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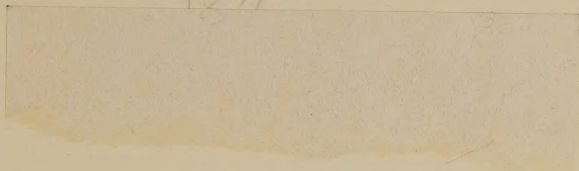
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ELEMENTS
OF
PSYCHOLOGY

An Introduction

PRENTICE-HALL PSYCHOLOGY SERIES

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ELEMENTS
OF
PSYCHOLOGY
An Introduction

BY
ALBERT CLAYTON REID, PH. D.

PROFESSOR OF PHILOSOPHY AND PSYCHOLOGY
WAKE FOREST COLLEGE

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TO
E. F. R.

Preface

THE first psychology laboratory was established only sixty years ago. Hence, the science of psychology is filled with the imperfections of method and the inadequate statements of fact common to any immature science. The present number of psychology laboratories is large; the amount of experimental work is enormous; the published reports of experimental investigations fill volumes. Nevertheless, psychologists in general as yet have adopted no common point of view, and they have formulated no laws that are comprehensive and satisfactory. Such conditions offer attractions, as well as handicaps, to introductory students and to mature investigators.

Moreover, psychology suffers from the evils of current popularity. The public uses the word "psychology" indiscriminately; writers have commercialized the superficial interest exhibited by the public; and charlatans have abused and discredited psychology in the opinion of many intelligent people. The vast majority of students, as a consequence, begin the study of psychology under the unfortunate misapprehension that they know something about the field; they are unwittingly embarrassed by prejudice or by the confidence of ignorance.

The present book is based on lectures prepared for the introductory student only. They were designed to give him a sound conception of experimental psychology and to pre-

pare him for advanced work in the field. To this end, a general simplicity of style and treatment has been maintained. Numerous technical facts and discussions have been omitted in order to prevent the student from becoming confused by details. These details may be supplied, if the instructor wishes, by reference to the many excellent books listed in the bibliography.

The obligations of the author are too numerous and varied to be listed here. His claim to originality lies in the choice, interpretation, and simplicity of arrangement of materials. He is greatly indebted to his teachers at Cornell University, especially to Edward Bradford Titchener, whose lectures and whose books were at once one's inspiration and despair. The reference readings at the close of each chapter and the bibliography at the end of the book are offered for the convenience of students and in appreciation and recognition of authors to whom this writer frequently turns. C. H. Stoeltz Co., of Chicago, graciously furnished numerous illustrations of psychological apparatus. Charles M. Allen, Jr., gave invaluable assistance in the preparation of the illustrations. Dr. Edgar H. Henderson, Professor of Philosophy at Meredith College, read the manuscript and offered numerous helpful suggestions; for his generosity and constructive criticism I am deeply grateful.

A. C. R.

WAKE FOREST COLLEGE

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CHAPTER I

Introduction

PSYCHOLOGY is the study of mind. The psychologist regards the mind as real. He assumes that mind exists in its own right and has its own basic characteristics and modes of activity, just as certainly as the physicist and the biologist claim the existence of physical substance and life for their respective fields.

Of course there arise numerous metaphysical problems which will be solved at no early date, if ever. Obviously the mind is intimately associated with the biological organism, and likewise the mind is manifestly dependent upon inanimate physical existence. For example, no one has experienced disembodied consciousness, nor has one observed life dissociated from physical substance. Such close association and apparent interdependence do not, however, warrant the assumption that mind is essentially either physiological or physical. Let it be said then, once and for all, that mind is as much a fact as is life or physical substance, and that the field of psychology is the mind. The subject matter of psychology consists, therefore, of mental phenomena—sensations, images, affection, perceptions, reason, and other modes of psychological processes.

Restrictions of descriptive psychology. Descriptive psychology, by definition, is restricted to observable phe-

nomena and to inferences based upon observed phenomena. Descriptive psychology is, therefore, not concerned with various prevalent interests, such as mental telepathy, clairvoyance, spiritualism, and extrasensory perception, which have as yet gained no valid place in science. Furthermore, like biology and physics, descriptive psychology does not pretend to embrace or to speak *ex cathedra* about the primary tenets of religion. The purpose of psychology is the study of the mind, and not an investigation or appraisal of facts in other fields.

As valuable and fascinating as these other subjects may be, the introductory student should confine his investigation to the mind of the normal human adult. Children and abnormal people rarely give reliable reports of mental states, while the nature of the mind of a lower animal must be inferred from the animal's physiological responses to stimuli. Although a large amount of work has been done in the realms of child psychology, abnormal psychology, social psychology, and animal psychology, one can understand such work satisfactorily only in the light of knowledge of the normal human adult's mind. Moreover, the opinion of the average layman is scientifically worthless. Irrespective of the fact that one's states of consciousness are one's most obvious experiences, the average person takes mind for granted. He is no more interested in its essential nature than he is in the chemistry of a dinner; consequently, his assertions about mind are usually of no scientific value. The highly trained psychologist, however, does observe closely the various types of mental states, and he notes their indispensable characteristics and their modes of activity. His technical description

of mind and the laws of mind which he formulates are, therefore, of primary importance.

Historical references to mind. The direct and indirect historical references to mind are too numerous to list. Although scientific psychology first appeared during the last quarter of the nineteenth century, both the secular and the religious literature of the last three thousand years abound with references to mind. For example, one may read Homer and Hesiod as a psychological treatment of the early Hellenic people, or the Bible as a graphic psychological treatment of the Hebrews and other Orientals. The citation of a few cases is adequate to our needs here. Cambyses, of the sixth century B.C., suffered from a mental disorder similar to epilepsy. Cleomenes, king of Sparta, in fits of madness would strike with his sceptre any Spartan he would happen to meet, and finally, in 491 B.C., he committed suicide by stabbing himself with a knife. Cain exhibited a perverse attitude which led him to commit murder. The description of social conditions just prior to the Flood are as suggestive as they are graphic. Events in the family of Noah are evidence of refinement and depravity of mind. Saul displayed recurring periods of depression which can be characterized as melancholia. David on one occasion feigned madness. Nebuchadnezzar was undoubtedly insane when he thought himself an animal and "did eat grass like an ox." Moreover, the influence of thought upon conduct is frequently specified by both secular and religious writers.

Greek philosophers definitely emphasize the existence and importance of mind. Anaxagoras (500-428 B.C.), an Athenian philosopher, was the first man to speak of mind as such,

and to insist upon the existence of mind as a metaphysical reality essentially different from matter. For him, substance consisted of an infinite number of materialistic elements, or spermata. Mind, however, was *Nous*, thought-stuff, reason, an existence which was self-motivating. For him, *Nous* embraced both human reason and universal law. The Greek Sophists, presupposing the existence of mind, emphasized the empirical nature of thought, and reduced knowledge to the status of opinion. With them appear for the first time many of the persistent and fascinating problems of epistemology. Socrates and Plato revolutionized philosophy by the emphasis they placed upon the nature of man, the inadequacy of empiricism, and man's ability to become aware of ultimate reality. Plato's doctrine of mental hygiene, in principle, has not been excelled. In his work, *De Anima*, Aristotle presented a speculative treatment of the nature of mind. He formulated "laws" of association, and he may be regarded as the first man to undertake a scientific examination of the human mind. Later the Stoics considered mind a universal, spiritual principle. They thought that body as such should be regarded as secondary to mind, and thus they attracted much attention to mind.

Modern scientists and philosophers became deeply interested in mind. Following the theologically turgid and the scientifically sterile Middle Ages, a galaxy of scientists and philosophers appeared, who, more and more adequately, prepared the stage for the appearance of psychology. A partial list includes the following men: Descartes (1596-1650), who insisted upon a dualism of mind and body, and asserted that the basic attributes of mind are unlike those of matter; Francis Bacon (1561-1626), who called Western civilization

to the task of descriptive science; Galileo (1564-1642), who proposed restrictions with regard to science; Berkeley (1685-1753), who proclaimed an extreme form of subjectivism; Locke (1632-1704), who emphasized the empirical nature of mind; Hume (1711-1776), who, with uncanny ability, attracted attention to the scope and inferences of empiricism; and Kant (1724-1804), who, with the genius of a Scotchman and the academic efficiency of a German scholar, insisted upon a serious and exhaustive study of the human mind itself as prerequisite to the solution of problems in other fields. Later, James Mill (1773-1836), John Stuart Mill (1806-1873), and Herbert Spencer (1820-1903) were influential. Such philosophical problems as empiricism, positivism, agnosticism, humanism, and idealism led men toward the realization that the solution of such problems is to be found in the field of the mind. It was realized then, as now, that epistemology holds the key to many doors.

In the early part of the nineteenth century, scientists were attracted to mental phenomena, and began to examine them with a measure of scientific care. Four men especially deserve to be named here: Weber, who experimented with sensation and formulated a "law" that carries his name; Fechner, who published his observations and opinions concerning psychophysics; Helmholtz, whose work in vision and audition is monumental; and Hering, who offered theories of vision which are now widely accepted. It was thus indirectly from philosophical interests and directly from a scientific background that the first psychological laboratory appeared during the last quarter of the nineteenth century.

Conceptions of mind. It is interesting to observe that very few people inquire about the nature of mind. Almost

everyone admits the existence, or subsistence, of mind, but only a very few people have tried to discover what it is. Some widespread opinions should, therefore, be listed here, in order that one may arrive at a satisfactory conception of mind as such.

Mind as supernatural. One of the most prevalent theories is that mind is supernatural—a notion extending back to primitive man. Early man had about the same mental capacity, the same primary environment, and the same primary interests that modern man has. He did not have the information possessed by civilized man. Primitive man interpreted things and events in terms of his own nature and experience; he himself was the most familiar object of his experience. He, therefore, personified shadows and images, great natural objects and phenomena, and the operations of his own mind. For instance, the experiences which he had in dreams, in deliria, and during trances meant one thing primarily—that there was some intangible spiritual part of his body which at times was able to leave the body. The belief persists today, resulting in an unwarranted tendency to make mind and soul identical. This conception implies that mind is intangible and unobservable, and consequently cannot come within the domain of science. It lends itself, moreover, to numerous misleading and confusing notions of the way in which mind functions.

Mind as universal principle. Among those who hold mind to be a universal principle are Anaxagoras, the Stoics, and a long and almost unbroken chain of mystics. In more recent years, Spinoza, Berkeley, and Eddington offer interesting conceptions. For Berkeley, *esse est percipi*. He insists that existence is mental, an assumption as fascinating as

it seems untenable. Spinoza begins with the idea that God is the sole, independent substance, the ultimate upon which all other substances depend. Everything is dependent upon him; there can be no substance outside of him. For Spinoza, mind itself is not the ultimate; it is an attribute of the ultimate. Eddington, in the following pertinent statement, reflects a significant attitude of some contemporary scientists:¹

Mind is the first and most direct thing in our experience; all else is remote inference. That environment of space and time and matter, of light and colour and concrete things, which seems so vividly real to us is probed deeply by every device of physical science and at the bottom we reach symbols. Its substance has melted into shadow.

Mind as naturalistic phenomena. The naturalistic point of view of mind dates from the Greek philosophers, Leukippus and Democritus, who reduced mind to the status of round, smooth, light, highly mobile atoms existing in the brain. Thinking occurs, they said, when such atoms are in motion, and ceases if and when they become static. In the last half of the eighteenth century, Cabanis, a French physiologist, declared that the universe and all of its phenomena could be reduced to a naturalistic basis. He asserted that mind is an activity of the nervous structure and said that the brain secretes thought as the liver secretes bile. Thomas Hobbes suggested that the brain gives out thought as a candle gives out light. Consciousness, for Hobbes, was merely an epiphenomenon, and therefore not actually different from the brain substance from which it arises.

¹ A. S. Eddington, *Science and the Unseen World*, p. 37. New York: The Macmillan Company, 1930. By permission of the publishers.

Behavioristic psychologists are also exponents of naturalism. They deny the existence of consciousness and urge that the field of psychology consists of organic behavior only. According to Watson,² behaviorism "is different from physiology only in the grouping of its problems. . . . [It] is intrinsically interested in what the whole animal will do from morning to night and from night to morning." Hoisington emphatically states:³

Mind, let it be said once and for all, is nothing over and above bodily responses. . . . Mind, psychologically defined, is integrated sensory-motor responses, and psychology is the study of the nature and origin of these responses, their integration into patterns, and their functioning in our daily lives.

The common-sense conception. The masses of people have the habit of thinking in terms of what one may call uncritical, naïvely acceptable, intelligible, common-sense terms. The popular conception of mind, as Titchener points out, is that "mind is a living being, with all the qualities and powers that are possessed by material living beings; an immaterial animal, so to say, that dwells within the material animal; an inward man, manifesting itself in the behaviour of the outward man."⁴ The average layman, if he reflects at all about the mind, regards it as an immaterial substance which is free and unrestricted by the data which it has acquired or by any laws. He would also say that the mind is very valuable, both intrinsically and as an instrument for directing the biological organism. In general, for him mind

² John B. Watson, *Behaviorism*, p. 11. New York: W. W. Norton & Company, Inc., 1925. By permission of the publishers.

³ Louis B. Hoisington, *Psychology*, p. 2. New York: The Macmillan Company, 1935. By permission of the publishers.

⁴ Edward Bradford Titchener, *A Text-Book of Psychology*, p. 11. New York: The Macmillan Company, 1928. By permission of the publishers.

is an intangible, somewhat spiritual endowment, a manikin whose actual nature and modes of growth and behavior he never considers and whose freedom he never questions.

The scientific point of view. In many respects in opposition to the general notions concerning mind, the scientific psychologist assumes that mind is describable, that its data can be known, and that it is governed by its own laws. He does not claim to know what mind is. He does formulate "working" definitions of mind, just as the physicist must have a definition of matter and the biologist a definition of life. Descriptions of consciousness are not easily made, nor are the laws of mind readily discovered. It is impossible to define either mind or life or matter absolutely; but a scientist, having established working hypotheses, can proceed with his investigations more satisfactorily than he otherwise could. In comparison, other scientific work seems to be less difficult and more successful. Nevertheless, even if he must do so somewhat arbitrarily, the experimental psychologist proceeds with the fundamental assumption that mind is both describable and lawful.

The birth of experimental psychology. It was out of the background of philosophy and science, as has been stated, that the first psychological laboratory appeared. This laboratory was established by Wilhelm Wundt, in 1879, at the University of Leipzig. William James, it is true, equipped a room at Harvard sometime between 1874 and 1876, but it is conceded that the equipment was used primarily for classroom demonstration. The founding of the laboratory at Leipzig should be listed along with the birth of formal philosophy in 585 B.C., the appearance of Copernican astronomy in the sixteenth century, and the publication of Dar-

win's *The Origin of Species* in 1859, as one of the epoch making events in academic history. It was then, for the first time, that the human mind was brought into a psychological laboratory to be subjected to experimental examination. In this laboratory Wundt proposed to describe states of consciousness as such, and thus to obtain scientific data with which to formulate laws of the mind. His laboratory soon attracted many brilliant young men. Among his students were to be found Alfred Lehmann, O. Külpe, Frank Angell, Stanley Hall, E. B. Titchener, J. McKeen Cattell, H. C. Warren, C. H. Judd, and others who, in Europe and in America, were to be largely responsible for the development of experimental psychology. Before 1895, laboratories were established in Europe at Freiburg, Göttingen, Berlin, Bonn, Munich, Zurich, and Halle; and in America, at Johns Hopkins, Pennsylvania, Cornell, Clark, Indiana, and Wisconsin. As a science, psychology has not yet reached maturity, but its growth has been phenomenal.

The common-sense and scientific points of view contrasted. We have labeled the attitude of everyday life as that of common sense. As a rule, this attitude is childlike and uncritical. It consists of a medley of traditions, superficial observations, and interest in applications and values. For example, objects are regarded as ultimate fact; they are only what they appear to be. To the child, an apple is only an apple, a tree is just a tree, a primrose is merely a primrose. The chemical nature of the object is not considered; its atomic structure is never thought of; the genetic factors involved in its development are unnoted. Common sense does not assume the task of trying to discover the essence of

an object; it is more concerned with its mere appearance, its usefulness, its desirability, and its cash value.

Moreover, the common-sense attitude does not lead one to investigate adequately the problem of cause and effect. If *B* follows *A* immediately, then *A* is too readily regarded as the cause of *B*. Sequence, therefore, comes to be thought of as cause and effect. Also, supernatural intervention is frequently considered the cause of many events in the natural realm. Evil spirits may be regarded as the cause of famine or flood or disease. Benevolent spirits, on the other hand, are thought to bring bountiful harvests, health, and good fortune generally. Moreover, physical events are frequently regarded as brought about by divine intervention. Man is, furthermore, inclined to endow the world with his own characteristics; he projects himself into natural phenomena, and so he personifies and attributes purpose to many natural phenomena. Night is made for rest; it rains in order that grass may grow; the air was made for one to breathe; the sun shines in order that food may be produced; and lightning kills a man that other men may be taught a lesson.

Technology as common sense. Furthermore, common sense emphasizes technology, that is, the application of known facts. The physician is a technologist, for he is interested in the application of scientific discoveries. Likewise, an engineer must consider the strength of a bridge he designs; the inventor is influenced by the usefulness of his invention; the manufacturer is concerned with the utility of his products; the teacher is anxious about the ultimate success of his students. In general, people are interested in the values to be derived from scientific facts and not in the facts

themselves. Even mind is usually considered in terms of cash values.

Descriptive science. Descriptive science, on the other hand, seeks facts as such. In contrast with the point of view of common sense, the scientific attitude is highly critical. The descriptive scientist undertakes to make a photographic presentation of experience stripped of all meaning and values. The scientific point of view is reached when one assumes the attitude of wishing to discover the *what* and *how* of experience. Thales and Galileo and Millikan became scientific when they endeavored to discover the fundamental facts about the world. Wundt and Titchener were scientific when they undertook to discover what mind is. Newton was scientific when, on the basis of observed phenomena, he tried to state the law of gravitation. The purpose of science, then, is to discover observable facts and to formulate scientific laws. Modern pioneers in science include da Vinci, Vesalius, Copernicus, Galileo, Francis Bacon, Kepler, Priestly, Boyle, Newton, and others, who have endeavored to place the world of experience upon the rack and make it reveal its secrets.

Modern descriptive science may be said to have had its birth when Galileo, in two celebrated maxims, declared (1) that science must be independent of all authority except itself, and (2) that all inferences of science must be derived from observation and experimentation. This dual pronouncement was designed to accentuate two matters of primary importance to science. First, science must be freed from Scholastic speculation and religious domination. Galileo knew that Roger Bacon had been imprisoned, that Bruno had been burned at the stake, and that numerous

others had been subjected to the tortures of the Inquisition. Second, the limits of science itself must, in principle, be established. Science must not exceed its domain any more than religion should be permitted to dictate to science. Galileo, therefore, insisted that descriptive science should confine itself to the realm of observable facts. Scientists have generally approved the policy established by him. Francis Bacon, however verbose, emphatically proposed experimentation, and formulated rules to govern experimental science. From their time on, critical science has, for the most part, endeavored to conform to the requirements proposed by these pioneers.

Some of the characteristics and conditions of scientific observation should be considered. First, observation occurs directly through sensory experience. The sense organs are the means one has of coming into direct contact with one's environment. Observable states of consciousness possess, in general, the characteristics of sensory data. For illustration, a visual image, like visual sensation, is color or gray in quality; an auditory image has a quality of tone or noise. By direct observation, then, one means seeing, hearing, smelling, and experiencing tactually as such. It is, for example, the red, or the blue, or the sweet, or the cold that exists as a state of consciousness. Second, observation may occur indirectly, as through the logical treatment of the data obtained by direct observation. A mathematical treatment of the movement of other planets pointed to the existence of hitherto unobserved planets, namely, Neptune and Pluto, which the telescope subsequently exposed. The electron is too minute to be seen directly, nevertheless the mathematical treatment of observed facts reveals the existence of the electron or its

equivalent. The physical substratum of light has not been experienced directly, but the existence of something like pendular vibrations or corpuscular activity is beyond question. Likewise, life itself has not been observed, but its manifestations leave no doubt of its existence.

What types of knowledge other than those within the sphere of *observable* facts exist? Science does not pretend to say; it is not within the province of science to make claims about other fields. It is, therefore, by direct and indirect observation that the data of descriptive science are obtained; and it is from observed sequences of phenomena of a given field that scientific laws are formulated. Newton, for illustration, inferred the law of gravitation from observations he had made of falling bodies.

Conditions essential to scientific observation. There are conditions indispensable to correct observation. The attitude of the observer must be impersonal. Prejudice and personal desires must be eliminated, for one may project experience from one's own mind and thus risk observing that which one anticipates. The scientist wishes to discover the facts. "Never mind what you believe you will find in that section of nerve; discover what is there and report that only!" was the advice hurled by a brilliant old experimental physiologist at two students in his laboratory. Moreover, every known condition associated with the experiment should be controlled. Furthermore, the experiment should be repeated as many times as may be necessary in order to reduce the probability of error to a minimum.

The field of science. As we have said, descriptive science is concerned with observable phenomena and with inferences based upon observed facts. By definition, the limits

of science are theoretically fixed by the possible scope of observation. Any experience which appears within the limits of observation, whether electrons or the solar system, a nervous impulse or a state of consciousness, is of the domain of science. But what are the objects of observation? What are observable facts? They are experiences that are palpable, tangible, persistent, and which cannot be argued away. Experience associated with substance cannot be argued away. Cardiac activities, nervous impulses, and the endocrines exist irrespective of what one believes. But are mental states palpable? In reply, let us say that, psychologically, red is red, a tone is tonal, and quick pain is pain regardless of logical treatment and irrespective of any form of argument. Such experiences stand up under observation, and their indispensable attributes can be noted.

The nature of experience. But the problem of what constitutes the essential nature of experience arises. Is descriptive science concerned with physical objects only? Is it restricted to external material substance which may be examined in terms of mass, extension, and time? Scientists, except for convenience, seem no longer to think in terms of physical objects. They regard objects, as such, as modes of appearance only, while models are devised merely as aids to interpretation. Phenomena or processes now seem to constitute fact and become the objects of scientific investigation. The quantum, for example, is apparently a locus of energy; life consists of modes of activity; mind is a sequence of processes.

The unity of the field of observable experience. Another pertinent fact is that the field of experience is one. As stated before, there has been no actual division of the general field

of science into different unrelated parts; the classification is an arbitrary one, and not absolute. For example, when a shrub grows, data of both chemistry and biology are involved. When an animal breathes, chemical factors and biological processes are present. And when an observer witnesses the activity of the plant or animal, body, life, and mind are involved in the experience of observation. Moreover, matter, life, and mind are all known through the medium of mental processes only; there is no other means by which scientific observation can be made.

In other words, it may be said, then, that the different sciences may be regarded as merely different points of view of the one world of observable phenomena. A particular science, therefore, has its birth when some critical observer takes one point of view of the world of experience and undertakes to state the *what* and the *how* of the world of experience as observed from that point of view. Physics, for example, was born when a Thales or an Aristotle tried to discover the nature of experience as observed from the point of view of inanimate physical matter; biology appeared as a science when a Vesalius, a Mendel, or a Darwin examined it from the point of view of living matter; and psychology arose when a Wundt undertook to describe experience in terms of consciousness.

Since, therefore, descriptive science in general deals with the world of experience, and since observation determines the limits of science, the data of a particular science may be defined as a large body of related facts observed from one point of view. The laws of a given science are formulated on the basis of the relation of the data to each other and their modes of behavior under given conditions. For ex-

ample, if a triangle be used to represent observable experience, then physics may be considered as one side of the triangle, biology another, and psychology still another; while Boyle's law, the all-or-none law, and Weber's law are derived from the observed facts in their respective fields.

The sciences defined and contrasted. Physics is the science of inanimate matter or of physical phenomena. Physical substance is usually regarded as inanimate, having extension and mass, and moving through impact. Energy and matter, in their totality, remain a constant. Since this discussion is looking toward a scientific treatment of mind, the physics of color and of tone may here be considered as familiar and convenient illustrations of physical phenomena. Physically, color is, according to one theory, the wave motion of ether or of some other physical medium. The longest waves and the shortest waves of the color spectrum are approximately 760 *uu* and 390 *uu* respectively. A *u*, or micron, is equal to one-millionth of a meter, or 0.000039 inch. A micromicron, *uu*, is 0.00000001 millimeter, or 0.00000000039 inch. These wave motions travel at the rate of about 186,000 miles a second. To be specific, red consists of wave lengths of about 760 *uu*; yellow, about 574 *uu*; green, about 505 *uu*; and blue, about 478 *uu*. A tone, physically, is the periodic vibrations of a physical medium, which vibrations have a given vibration rate and speed. The tone *c'*, for example, may be produced by a fork having a vibration rate of 256 v.p.s. Thus, color and tone, as well as other parts of the field of physics, may be regarded as physical substance moving in space and time.

The field of physical science is a vast one which itself allows many different modes of investigation. It falls into

many divisions, as astronomy, chemistry, physics, civil engineering, hydraulic engineering, electrical engineering, and geology. Physics embraces the whole realm of inanimate existence, from the atoms to the stars.

Biology, however, restricts its interest to living matter. Biology is the science of life, or of living phenomena. While life as such is transcendent, living matter has characteristics which, as we now know them, are fundamentally different from those of inanimate matter. For example, living matter is irritable; amoeba or man responds to stimuli. It is capable of anabolism, that is, the organism grows toward maturity, and, if injured, normally undertakes to repair itself. Moreover, it reproduces itself sexually or asexually. Let us again use the simple illustrations of color and tone. Color, from the point of view of biology, is nervous activity started in the rods and cones of the retina and transmitted by afferent nerves to the occipital lobe of the cerebral cortex. Sound, likewise, is the nervous impulse initiated in the inner ear and carried centrally over the auditory nerve. The difference, therefore, between the point of view of physics and that of biology, as shown by these illustrations, is obvious.

The world of living matter is also divided into several parts for convenience of study. One may here name, as a partial list, biology, botany, zoölogy, embryology, neurology, cytology, pathology, histology, anatomy, and bacteriology.

The third point of view of the world of observable experience is that of psychology, or that which permits the observation of the mind. Psychology is the science of the mind. The psychological scientist is interested in states of consciousness; he examines the modes of behavior of states of consciousness; he seeks to know what they are and the nature

of the laws that govern them. This point of view is a legitimate one for two reasons. First, states of consciousness are one's most intimate and conspicuous observable experiences. They are processes about whose existence one is, after all, most certain. For example, the white and black of this page are more obvious than are the atoms composing the paper, or the nervous impulses passing from one's eye to one's brain. Second, basic characteristics of mind are essentially different from those of physical substance or of life.

Let us note some interesting facts about mental states. Consciousness has the characteristics of awareness. In some way, thought is aware of its own existence; and, regardless of problems of logic, it may observe its own self. Mind is also capable of recognition. It not only recalls past experiences; it also identifies them as of the past. Moreover, mind is capable of predicting. One anticipates or imagines that a snowfall will occur tomorrow, that severe cold will occur next week and that springtime will eventually appear. Furthermore, mind has the peculiar characteristic of being capable of creation, or of effecting the equivalent of creation. Of course it cannot produce something out of nothing. But the mind can combine several of its data to form a new mental datum, and at the same time retain the data used. For example, one may combine many visual images of a house, and thus imagine a new house, and at the same time retain the old images. It is as when one uses the letters of the alphabet to form words; the alphabet is not consumed as one constructs one word and then another. None of these characteristics belongs to biology or physics as such.

Finally, let us note that color as such is a condition of

consciousness. Red, psychologically, is neither wave motion nor nervous impulse. One's memory of red may exist independently of either the physics or biology of immediate sensory experience, as such, as now known. Likewise, a tone is the actual auditory experience. It is not the sound waves or the nervous impulses. Sound waves and nervous impulses may, of course, occur without the attendant consciousness of sound; and the memory of a tone may occur without concomitant physical or sensory phenomena.

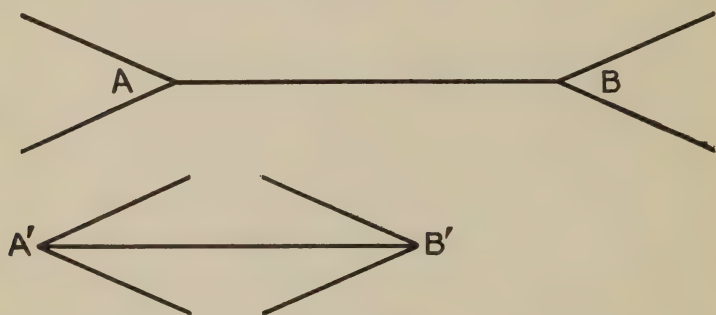


Fig. 1.—The Müller-Lyer Illusion. (Section A-B is the same length as section A'-B'.)

Time, space, and mass offer other clear illustrations of the difference between physics and psychology. The second is a constant physical unit in any part of the world. The minute does not vary in duration. Psychological time does vary, as anyone knows who has experienced a pleasant evening, waited for a train, or anticipated an initiation. The centimeter is a constant unit of physical measurement. Standards of physical measurement are fixed. But psychological space does not necessarily conform to physical facts. The Müller-Lyer illusion and the Poggendorf illusion are

cases in point of such discrepancies between physical space and psychological space.

Moreover, the gram is a constant unit of weight; the pound is one pound. Yet, as Weber's law clearly shows, there is a wide variation between the physical and the psychological. The proverbial pound of feathers, then, is not the same psychologically as the pound of shot. Try this simple experiment: Hold a large sponge on the palm of one hand and a steel ball on the palm of the other. The steel

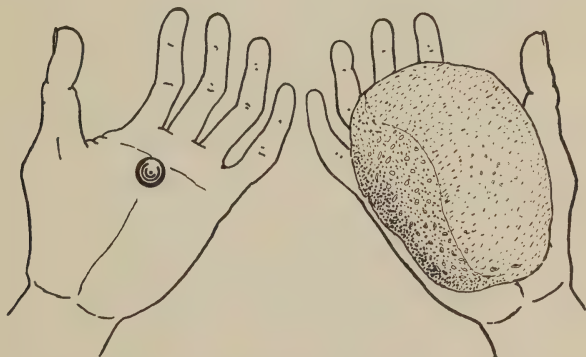


Fig. 2.—The Steel Ball—Sponge Illusion. (One usually perceives the steel ball as being twice as heavy as the sponge, although the sponge weighs twice as much as the steel ball.)

ball will likely be judged to be twice as heavy as the sponge, when in reality the sponge weighs two and one-half times as much as the steel ball. The physical weight is a fact and the psychological is also a fact; they occur as from two different modes of observation.

Relation of the subject matter of the sciences. We have said that the world of observable experience is one; and

we have pointed out basic differences between physics, biology, and psychology. What is the actual relation between matter, life, and mind? Physical matter, so defined, extends, as has been stated, from the smallest microscopic particle on the one hand to the stellar universes on the other.

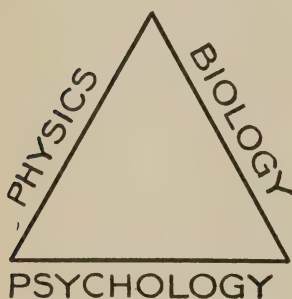


Fig. 3.—The Relation of the Three Descriptive Sciences.

Life is associated directly with only a small part of the physical world. Mind is directly related to only a small portion of living matter. One may say, with reasonable safety, that mind is to be found only in animals having a nervous system, and that mind is dependent upon the nervous system. But the relation here indicated does not necessarily mean

identity, and it certainly does not reduce mind to a condition of matter. What, then, is the relation of mind and body to each other? Several theories have been proposed; none of them, however, can be considered valid.

Dualism of body and mind presupposes that body and mind are two separate and basically different entities which constitute man, if not lower animals also. According to some dualists, mind affects body and body influences mind. For instance, one weeps because he is sad, laughs because he is happy, is mentally inefficient because he is ill, and mentally alert because of endocrine secretions or the influence of drugs. Psychophysical parallelism assumes that mind and body are two aspects of the same world of experience. They, therefore, like the two sides of a plate or as the palm and the back of one's hand, do not affect each other, but,

so to say, move parallel to each other. Any change in body is accompanied by a like change in mind. One is not afraid because one's hair stands on end and one's respiratory and cardiac rates vary from the normal, nor are these organic changes caused by mind; the organic changes and the mental changes are all a part of a total process. They are merely manifestations of one and the same substratum.

The triple aspect theory likewise regards body, life, and mind as three aspects of the same ultimate existence or substratum.

Call the ultimate *X*, if you wish. The *X* is the tri-

angle; body, life, and mind are the three sides of the triangle.

Psychology as science. The principles which have been stated concerning science are directly applicable to the field of scientific psychology. It is assumed, therefore, that mind may be described, and that laws may be formulated to indicate modes of behavior of mental processes.

Mind and consciousness. For descriptive psychology, mind is defined as the sum-total of an individual's states of consciousness as experienced during his lifetime. One does not know of mind prior to birth or after death. Moreover, one does not experience subconsciousness. Subconscious mind, if it exists, is outside of, or transcendent to, the realm of consciousness; and one can be conscious of only what appears in, or as, consciousness. Consciousness is one's mind at a given moment, during a given *now*. It is not a static condition, nor is it an independent unit separate and apart from all other states of consciousness. A state of conscious-

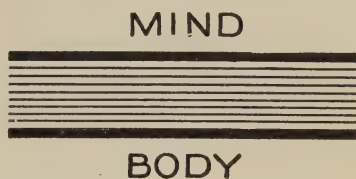


Fig. 4.—Psychophysical Parallelism.

ness is not, then, an integral unit, as a grain of sand in a dune or a shot in a bag. It is an active existence, a process, which may be simple or complex in composition. The red one sees, the tone one hears, the pain one experiences, the odor one smells, or the sour one tastes is one's consciousness at a given moment. Likewise, the image of a red, or of a tone is one's consciousness. Also, complex sensory or imaginal experiences may constitute one's consciousness as of a given moment. It should furthermore be noted that perceptions and ideas may be experienced at a given instant, and, when once formed, may be retained and reproduced as a mosaic or unit of experience.

The integration of mental phenomena. Mind is frequently referred to as a stream of consciousness. In some respects mind does flow as an unusually complete integration of mental states. One experience is linked or fused with another. For example, suppose one sets the rider of the metronome pendulum so that the instrument gives one beat every second. The ear is mechanical in operation, and so there is no afterimage effect or prolongation of the activity of the sense organ. Yet beats 1 and 2 and 3 and 4 do not stand alone as entirely separate experiences. They are each active processes which become associated as a series of interlocked experiences. As many as six beats may be thus united, and even six units of six beats each may be so joined together. Complex states, as meanings, may likewise become integrated, for ideas do not appear in staccato form but in unified sequence.

Moreover, mental states are phenomena or processes. They must not be regarded as physical units or sections.

Nor need one be troubled by the old question, how can a state of consciousness observe itself? A strict logic of mathematics or of objects need not apply here. Consciousness, let it be said once and for all, does not have to stand aside from itself to be aware of itself or to observe itself. It is not a physical object, nor is it dual in nature. It does not, therefore, conform to some conceptions of logic, for one does not need two minds, the one to experience a tone and the other to be aware that one is experiencing the tone. The experience of tone and awareness may be one. It is, then, in this way that mind is capable of observing itself, and able to describe itself.

Experimental method in psychology. In their efforts to describe mind, experimentalists follow in general the method employed by other scientists. They undertake to discover the essential nature of mind and the laws of mind. The work of the chemist affords a convenient analogy, although not a correct one. The chemist first analyzes a given substance. He reduces the compound to its elementary parts and then describes each element in terms of its indispensable attributes. For him, water becomes H_2 and O ; and he then describes hydrogen and oxygen. For him, crayon is $Ca + C + O_3$, salt $Na + Cl$. After the elements are isolated and described, they are recombined under known conditions and compounds thus formed. The psychologist, like the chemist, resorts to analysis and synthesis. He first endeavors to isolate and describe the mental "elements." He later brings elementary states of consciousness together under known conditions, that he may know the factors involved in the formation of compounds.

Mental elements and compounds. There are apparently three types of mental elements: namely, sensation, image, and affection. In time this list may be changed. Complex psychological experiences include numerous types of compounds, as perception, ideas, imagination, and reasoning. These compound states of consciousness may be formed in time, and, as has been stated, they may be retained as units and reappear in orderly sequences. These elementary and complex states of consciousness are studied descriptively, and records are made of their indispensable characteristics. The method is in general similar to that employed in the natural sciences. In chemistry and biology, hydrogen, carbon, paramecium, and a neuron are isolated and described photographically as nearly as possible. Likewise, physical compounds and complex organisms are observed and their characteristics stated. Their modes of activity, as they occur under known conditions, are listed. Likewise, the psychologist describes mental states, and notes modes of activity under controlled conditions.

But description is not all. To answer the question *what*, is insufficient. As I write these words, I have an auditory, tonal experience. There also appear in association with the tone, visual images of a railway train, steam, the station, trees, people, and a city toward which the train moves. I also remember that I heard the tone yesterday and that the same types of experience appeared in connection with it. Why do these associations occur? Where have the old thought processes been retained meanwhile? What becomes of mind when one is asleep or under the influence of an anaesthetic? What, indeed, is the cause of the consciousness of tone? It is necessary to turn to two obvious fields,

physics and biology, for a partial explanation. Mental processes appear parallel to nervous activity; and, according to our working knowledge of physical substance, biological structures are affected by physical phenomena. As stated before, consciousness is not identical in kind with physical or biological phenomena, but it may be explained in terms of parallel physical and biological phenomena. Psychology, therefore, very frequently employs physics and biology as means of explaining psychological states.

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CHAPTER II

Sensation

THE mind of the normal human adult is complex in its nature. In its development its processes become associated into intricate and complicated mosaics or fusions. Mind does not consist of atomic processes, yet, by analogy and for the sake of clearness, one may regard mind as somewhat similar to the physical world with respect to its modes of appearance. Chemical elements rarely occur in pure form; they are intermingled or associated with each other in relations that form compounds. Water, salt, alcohol, stone, marble, and a thousand other objects are compounds. When the chemist speaks in technical terms of chalk, he refers to it as CaCO_3 . If he is handed an unknown object, he suspects that it is a compound, and he subjects the supposed compound to exact tests in order to discover the elements that compose the compound. In this way he pursues his investigations in the field of chemistry until he has explored the entire realm of chemical substances and discovered the total number of chemical elements in the world. At present he believes there are ninety-three of the elements. It is obviously dangerous to undertake to teach by the use of analogy, but let us nevertheless keep the illustration of chemical elements before us during our study of sensation.

Of course mental elements are not to be regarded as iden-

tical with chemical elements; mind is not physical substance. Psychology, nevertheless, does undertake to determine the number of mental elements, and now offers three types of elementary experiences. It may be that this number will be changed, but, until it is, we must proceed upon the tentative assumption that the number is correct. These elements are basic; they are fundamental; it is of them that complex experiences, such as perception and reasoning, are formed. We understand that there can be no sulphuric acid without the elements and the relation H_2+S+O_4 , nor nitric acid except as $H+N+O_3$. Similarly, there can be no meaning, as "cigar," without its necessary constituent psychological elements. And, as the total number of chemical elements must be sufficient to form every type of physical compound, just so there must be enough types of elementary states of consciousness to constitute every type of psychological process, whether simple or complex. In the general composition of the mind, there are sensory experiences, images, feelings, perceptions, memories, reasoning, and emotions.

The elements must also be regarded, at least provisionally, as permanent in nature. Their indispensable characteristics must remain stable. Just as oxygen remains a chemical element having fixed characteristics, so a mental element is a permanent type of process which has characteristics permanent in their general nature.

The three types of elements. Psychology, as we have stated, is as yet relatively young and immature. No one can, therefore, now afford to be dogmatic with reference to the total number of mental elements, or presume to make final claims with respect to the indispensable attributes of the elements. There are, however, according to widespread

belief, three types of elements, namely, sensation, image, and affection. Sensations are the characteristic psychological experiences arising when a sense organ is stimulated. As examples of sensation one may mention the red one experiences when the retina is stimulated in a given manner, the tone one hears when the inner ear is affected in a certain way, and the pure warmth one feels when the skin is stimulated under given conditions. Image is the elementary stuff of ideas or states of consciousness that memory furnishes. One's memory image of a face, or a tone, or an odor is an illustration. Affection is the characteristic element of feeling and emotion. It is the coloring process which may attend or permeate sensations, images, perceptions, and other mental states, somewhat as blue colors ink or pink colors a rose, thus making the experience pleasant or unpleasant.

It must be understood, as has been said before, that these elements do not stand alone. They are not, when they appear, like "a shower of shot." Nor are they materialistic particles or epiphenomena. They are active, conscious processes. They are the data of which mind as such is composed; they are all mental; they are each a normal part of thought. Affection, for instance, is as distinctly a part of mind as is image or sensation.

Mental elements have indispensable attributes. When the chemist reduces the compound to its elements, he then describes them in terms of indispensable characteristics. They cannot be subdivided or analyzed, and so they must be described in terms of what they essentially are as experienced. For example, gold is yellow, malleable, ductile, a good conductor of heat and electricity, and has a specific gravity of 19.3. If a substance has the first four character-

istics, but its specific gravity is 14.8, the substance is not gold. Just so, a psychological element has indispensable characteristics, and it no more exists unless all these attributes are present, than a triangle can exist without three sides. As an example, visual sensation must have color or gray, or it does not exist. No one has had a visual experience unless it appeared as color or gray or some intermediate of the two.

Sensation defined. Sensation is the first of the elements we shall study. Let it here be understood clearly that, psychologically, sensation does not mean nervous impulses; it means a state of consciousness. Sensation, by definition, is an elementary state of consciousness, arising immediately after and as a result of the stimulation of a sense organ. The tone, *c'*, is a state of consciousness arising when the auditory sense organ is stimulated by a tuning fork vibrating at the rate of 256 v.p.s.; sweet is a state of consciousness appearing after a taste bud, or a group of taste buds, has been stimulated; and green appears when light waves of a given frequency affect the retina.

How may a sensation be described? If the experience is elementary or simple, it cannot be analyzed; it cannot be subdivided; all that one can do, then, is to state its essential characteristics. If one follows the requirements of descriptive science, one must describe the sensation in terms of its indispensable characteristics. Despite controversies about the attributes of sensation, let us say that a sensation possesses, according to our best opinion, the indispensable characteristics of quality, intensity, attensity, extensity, and protensity. These characteristics seem to be inherent, original, constitutive attributes of sensation, and are not accretions or additions to it. Such things as value, names, and uses are

additions to sensation, and so do not belong to sensation itself any more than commercial worth is an intrinsic part of a chemical element.

Attributes of a sensation. Explanation of the attributes is necessary here for the sake of clearness.



Fig. 5.—Schema Showing the Relation of the Attributes to Sensation.
(An attribute is a mode of appearance intrinsic to sensation.)

Quality is an identifying aspect. For example, in vision, the quality red distinguishes the red experience from green, or blue is seen as different from black, when the other attributes of the two observations are similar. Two tones may be similar in duration, intensity, extent, and clearness, but one is identified as *C* and the other as *D*; the only

difference is that of quality. One taste experience may be identical with another except in quality—the one is sweet, the other is sour.

Intensity is the characteristic of density or strength of an experience. Every sensory experience—pain, cold, tone, bitter—has some measure of intensity. Who ever felt a pain that had no intensity whatever? If there is no intensity, the sensation does not exist. For instance, if a grain of sugar is dissolved in a glass of water, the water will not have the quality of sweetness; the stimulus to sweetness is here so weak that the experience sweet simply does not exist. There are the limens of the minimum and the maximum intensity

of sensation, represented by the faintest tone and the loudest tone, respectively, which one may hear. Intensity is sometimes referred to as density, for the weak sensations, in pattern, seem less dense or less compact than do the intense experiences. For example, a deeply saturated red seems more compact than a red of poor chroma, a weak pain less dense than an intense one, a low tone less compact than one of high pitch. In general, then, the relation between intensity and density is very close. For instance, the more deeply saturated a color experience, the more compact or dense it is. A high tone, as c'' , is compact and dense in texture, while a low tone is diffuse and somewhat indefinite in structural composition. The same types of variations in structural patterns obtain in other sense fields.

Extensity means the dimensional attribute. The prevalent conception that only physical objects are dimensional is inaccurate. One usually commits the error of stating that mind is nonspatial. Mind is thought to be so intangible that it cannot be observed, certainly not extended in two or three planes. But even the casual observer must admit that a pain is not a theoretical point; it is spread out, and it is more or less tridimensional. Nor is a color observed as occupying no space. A blue may be the size of a pin point, or it may be very large; it cannot be observed as nonspatial. Then, too, listen to a tone from a Galton whistle, a tuning fork, an organ pipe, or a cannon. Each tone is experienced as voluminous; it is heard as relatively large or small, irrespective of the physical body from which it originates. If this at first thought seems strange, it is because one has perhaps never considered seriously the fact of the spatial characteristic of psychological states.

Protensity is the temporal aspect of an experience. It is obvious that a sensation lasts some length of time; the experience goes on in time. The experience may last only a thousandth of a second, or it may continue for several seconds. A tone exists for a while, and even the beat of a metronome lasts for a fraction of the second which it may indicate. But protensity means something much more significant than any unit of duration as measured by some physical instrument of precision—it is duration itself. It exists without reference to any chronometer or physical standard. Listen to the pure tone of a tuning fork; let your consciousness be restricted to the tonal experience itself. Without any reference to anything else, the experience seems to grow in time, to go on, to have a “going-on-ness.” It is as if the experience buds at the tip, moves forward, perhaps becomes elongated. This is perhaps the nearest known approach to pure time.

Attensity, or clearness, is even more difficult to explain and illustrate. It is the capacity of an experience to claim and to hold for a while a place in consciousness. An area of color, a sound, or a pain may force itself, as it were, into mind; and when it does, it becomes relatively clear in consciousness. The pressure on the soles of one’s feet may attract attention, and when it does, it comes into psychological existence. The pain in a tooth attracts one; the pain did not exist as such until it came into consciousness. This attribute will be discussed more at length in a later section of this work.

These attributes are each indispensable. They are as the sides of a pentagon or the facets of a cut diamond. They

may not all be obvious at one instant, but they are as essential to sensation as the sides of a triangle are necessary to the triangle. Try to think of a visual experience which has neither color nor gray, or an auditory experience which is neither tone nor noise. Such an experience cannot be had. Likewise, each one of these attributes is present if the sensation exists.

The stimulus error. In observing sensation, it is imperative that the observer guard himself against the stimulus error, for this type of error is frequently made. It is the tendency of the observer to associate the sensation with the physical object. Red thus becomes red paper, cold becomes ice, tone becomes a bell, and pain becomes a sore muscle. The object is not the experience, the physical instrument is not the sensation, and so the two must not be confused. Pure sensation is, of itself, meaningless. Unassociated, it is the state of consciousness itself. It is not even named. It is likely that an infant's first visual experience is gray only, and that his first auditory experience is sound only. With adults, pure experience rarely occurs. Patients suffering total amnesia, that is, a complete loss of memory, may, in an extreme condition of the affliction, be reduced to a condition in which they have approximately pure experience.

Sensations arise from five different sense fields and are so classified. These different senses are vision, audition, taste, smell, and touch. Touch consists of the cutaneous and subcutaneous or kinaesthetic areas and includes a large number of types of sense organs. The typical sensory experiences will be listed in subsequent sections of this study.

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CHAPTER III

Vision

THE problem confronting one in the study of vision is that of listing all the typical visual qualities, showing their characteristics, and stating their behavior in time and in relation to each other. One is, therefore, here interested in the visual experiences as such. The student of psychology must understand that it is the states of consciousness, not physics, which he is to examine. What is it, then, that the "world of looks" includes? One has only to look about him to note a vast number of sense qualities within the limits of his field of vision. There are grays, blacks, whites, reds, oranges, light greens, purples, and a score of other different visual experiences. But, if one examines the field critically, how many different qualities may be discovered? How many qualities are there which are, as black and white, essentially unlike each other, and how many are there, as pink or violet, which resemble other qualities? All these different qualities will fall, as we shall discover, into two groups, namely, those qualities that are essentially unlike each other, as blue and yellow, and those that resemble two or more qualities, as orange or purple or a light orange. In our discussion we shall call those that are qualitatively unlike each other primary, and those that resemble two or more other qualities intermediates.

Hue, tint, and chroma. There are three characteristics of visual sensations which should be kept in mind; they are the hue, the tint, and the chroma of a color experience. The hue is the color, as the red, the blue, the black, or the yellow. The tint is the relative brightness of the experience. For instance, a pink is lighter than violet, yellow is inherently brighter than blue. In the color pyramid—a double pyramid which shows the relation of the primary visual qualities to each other—yellow is placed nearer white than is blue because in brightness yellow is more like white than is blue. Chroma is the color saturation of a visual experience. The saturation may be the maximum, as the blackest black, the deepest red or the bluest blue one can see, or it may be a low degree of saturation as in the case of a faded or washed-out red or blue.

The primary visual qualities. There are seven primary visual qualities: gray, black, white, red, green, blue, and yellow. These qualities are called primary because they are essentially unlike each other, and because every one of the approximately thirty-five thousand other visual qualities resembles two or more of them. For instance, black and white are qualitatively unlike each other, red and blue are essentially different, and green and yellow bear no resemblance in quality. But there are innumerable illustrations of qualities that resemble two or more of these seven primary qualities. For example, there are the light grays, the dark grays, the oranges, the pinks, the browns, and the violets.

Gray is a primary visual quality, but it is not a color. The experience is, descriptively, a motley, bubbly, gray field, which is somewhat irregular in texture. It is usually more or less striated, or filled with irregular, thread-like lines.

Gray seems to have a very slight resemblance to blue, although the behavior of gray shows this bluish aspect to be different from blue itself.

Impure gray may be observed under various conditions. It is more often than not a part of our visual consciousness. Obviously, it is a part of one's field of vision when one is out at night or in a darkened room; and it appears when one looks at the corner of a room or at the trees or houses across the street. These impure grays, as seen under such circumstances, are so mixed with colors and are so intimately associated with physical objects that it is almost impossible to isolate the gray itself from the rest of the experience. Pure gray can be observed under certain conditions only. What are the optimum conditions for observing pure gray? First, the retinas, the part of the eyes sensitive to light, must be free of all stimuli to light. The observer should be in a darkroom which admits no light. Second, the retinas must be free of afterimages, for, even in a darkroom, the retinas, which function chemically, may continue to react for several minutes after they have been stimulated. For example, look at a light or a color for thirty seconds and then close your eyes; the light or color experience may be seen for as much as five minutes after the physical stimuli no longer enter one's eyes. But if the retinas have been rested for, say, ten minutes, and are then subjected to no stimuli, one may see the visual field of pure gray before one.

Gray is variously called neutral gray, cortical gray, and brain gray. It is called neutral gray because it obeys none of the laws of color vision. For illustration, if one fixates a red, adaptation immediately begins to occur, that is, the red begins to fade out and the experience becomes less and less

red, until finally the color vanishes completely. It is not so with gray. Observe gray indefinitely; it does not become less gray when thus fixated for a long period of time. Likewise, gray does not obey the law of contrast, induction, after-images, or cancellation. Gray is referred to as cortical gray, or brain gray, because the experience is theoretically sup-

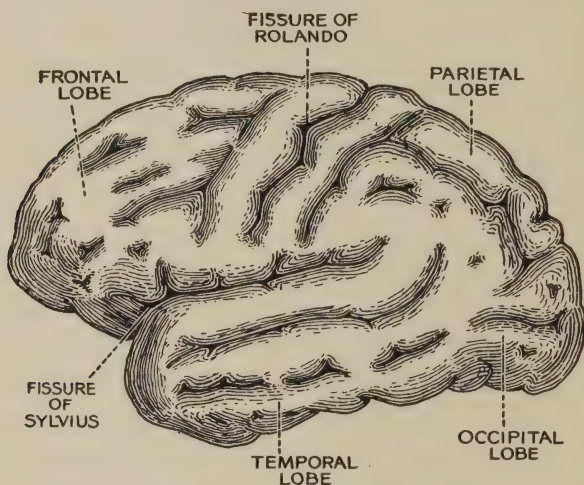


Fig. 6.—Lateral View of the Cerebrum. (The location of the major lobes and fissures will be noted. Theoretically, gray arises from activity of the occipital lobe.)

posed to appear in connection with the characteristic activity of the cortex of the occipital lobes of the cerebrum. Apparently the experience may occur without any simultaneous activity of the retina, and it is therefore assumed that it has its physiological counterpart in the brain. But, irrespective of these theories, it must be remembered that gray is a positive visual experience, and that it is just as much a fact as a visual quality as is any color. The absence of physical stimuli as applied to the retina makes no difference in fact here,

for in the absence of light or stimuli to color one does not see nothing or black; one sees gray.

The primary colors. There are six primary colors: black, white, red, green, blue, and yellow. This list does not correspond to the colors—*R, O, Y, G, B, I, V*—of the solar spectrum, but, as we shall see later, there is no actual conflict between the physics and the psychology of vision.

Psychologically, black is a primary color. What are the psychological facts in support of this claim? First, the visual experience is as much a fact as is blue or yellow or green. No one can deny that it is an actual visual experience, irrespective of its physical or biological basis. Second, black, as is the case with other colors, is seen only in the presence of light. Objects, which are observed as black in daylight, become gray in a darkroom or at night. Black cats are gray at night. Furthermore, black behaves generally according to the laws of vision, such as the laws of color mixture, contrast, adaptation, and afterimages.

There are various degrees of saturation of black. A section of black broadcloth is usually seen as very black. But when one places a piece of black velvet by the broadcloth, the velvet is seen as a much more deeply saturated black than the broadcloth. And, if one places the velvet by an object which reflects no light, as the end of a black tube or a stove pipe lined with soot, the velvet will be seen as a relatively poor black. Perhaps the most deeply saturated black one may experience can be had by projecting the afterimage derived from white upon the black interior of a tube which reflects no light rays. For instance, if one fixates a disk of white paper for about sixty seconds and then projects the negative afterimage upon the interior of the tube, one will see

a black disk which is itself more deeply saturated than the black area of the tube.

White is likewise a primary visual quality. It also is seen only in the presence of light; in darkness it becomes gray; and it obeys the laws of color vision. There are many experiences of deeply saturated white, such as the white of bond paper. But perhaps the whitest white one may normally experience can be had by placing a mirror so that it reflects the clear sky. Place a small disk of the whitest bond paper on the mirror, and the difference in the color saturation of the two will be so great as to make the white of the paper appear as a gray-white experience.

Red, green, blue, and yellow are so familiar as colors that one needs only to list them here. It perhaps should be said that, under optimum conditions, each one may be observed as having its maximum color saturation. As with black and white, there may be, on the one hand, the bluest blue one may experience, and, on the other hand, a washed-out, faded blue. There may be, likewise, the greenest green, the reddest red, and the yellowest yellow; or these colors may appear as washed-out color experiences.

The behavior of colors in space and time. The primary visual qualities behave in time and in relation to each other in very definite ways. An examination of them will reveal their behavior, their relation to each other, and the qualities and relative positions of the approximately thirty-five thousand intermediate visual qualities.

The relation of the visual qualities to each other. Let us begin the investigation of the relation by employing the suggestion offered by the solar spectrum. If one focuses a beam of sunlight so that it passes through a prism and then falls

on the screen, the beam of light will be distributed in such manner as to give a band of colors. This series of colors is the solar spectrum. The colors from red to violet are distributed according to wave lengths which occur in the physical medium transmitting the light waves. Now suppose we begin at the right end of the solar spectrum. The first color

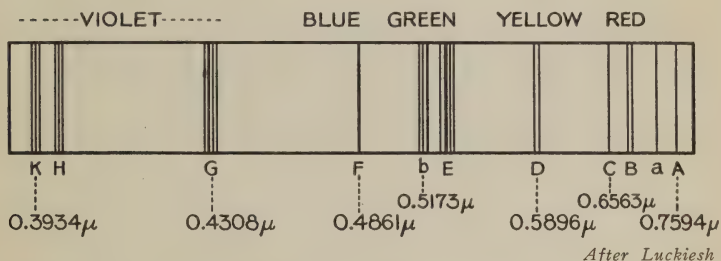


Fig. 7.—The Spectrum, Showing Generally the Values in Wave Lengths of Different Colors.

is red. As one passes toward the left, one passes from red through orange to yellow, from yellow through yellow-green to green, from green through green-blue to blue, and, finally, through indigo and violet, which resemble blue and red, apparently back toward red. There are, then, four primary psychological colors in the spectrum. One can show the relation of these four colors to each other by the use of the base of the color pyramid.

The color pyramid. This figure is closed from *B* to *R* not only because the spectrum seems to turn in the direction of red, but also because of actual relations between blue and red as color experiences. It will be noted that the line between red and yellow is a straight line. This is drawn thus because it consists of about forty distinguishable color qualities, each one of which is a simple, indivisible experience

which resembles the terminals. Each one of these intermediate qualities takes its particular place in the line by virtue of its relative resemblance to blue and yellow. For example, orange is a simple quality which resembles red and yellow equally, and therefore, appears midway in the series. An intermediate, as a red-yellow, would occupy a place nearer yellow, and a yellow-red would appear nearer red. Such a line, composed of simple qualities resembling the terminals, is called a qualitative

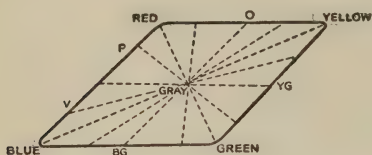


Fig. 8.—The Base of the Color Pyramid.

series. A series may be had not only between red and yellow, but also between yellow and green, green and blue, and blue and red, and between any two noncomplementary colors or between any color and gray. The primary colors which are complementary to each other are red and green, blue and yellow, and black and white. A qualitative series cannot exist between complementary colors. There exists no red-green, or blue-yellow, or black-white visual quality, for, as will be seen, complementary colors cancel each other when they are mixed.)

Let us, then, proceed to show the relation of the seven primary qualities to each other. For reasons that will be obvious later, in the color pyramid gray is placed in the center of the plane formed by *R*, *Y*, *G*, and *B*. In this plane qualitative series occur not only between the primary colors and gray, but also between each one of the intermediates forming the boundaries of the plane and gray. The plane

is thus found to be composed of several thousand visual qualities.)

Black and white, contrary to popular opinion, do not permit of a continuous series between them. They are complementary, and so mutually cancel each other when mixed in the right proportions. The psychological series in the line

extending from *W* to *Bk* run actually from black to gray, and from white to gray. Because of their relation to *R*, *Y*, *G*, and *B*, black and white must occupy the positions shown in the color pyramid. The skeleton of the color pyramid, a double pyramid, may be completed by indicating the qualitative series that exist between *W* and *R*, *W* and *Y*, *Bk* and *R*, *Bk* and *G*,

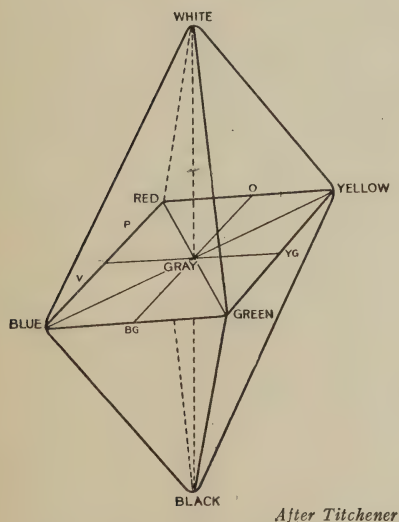


Fig. 9.—The Color Pyramid.

and so on. In the skeleton, it will be noticed that the series between *W* and *Y* is shorter than that between *W* and *B*. This is because, as was pointed out in the discussion of tint, *Y* is inherently lighter than *R*. *Y* is also inherently lighter than *R* and *G*. Furthermore, the corners of the pyramid are slightly rounded to indicate the fact that the various qualities do not form series that meet each other sharply—that is, that can be distinguished

from one another easily—at the places of conjunction.

Not only are there qualitative series as represented by the skeleton of the double pyramid; there are also simple qualities which resemble three noncomplementary qualities. For illustration, there is an experience which resembles *R*, *Y*, and *W* equally and which, therefore, falls centrally in the plane *RYW*. There are also intermediates which, by virtue of relative resemblance to *R*, *Y*, and *W*, occupy enough positions in this plane to make it a solid plane representing several hundred qualities. Intermediates likewise fill every other plane. And, if one should cut through the pyramid, one would discover that it is a solid one. The double pyramid, then, represents not only the seven primary qualities but also all qualities intermediate to two or more of these, a total of approximately thirty-five thousand distinguishable qualities. The double pyramid furthermore indicates, as will be seen later, the behavior of qualities in time and in relation to each other.

The laws of color vision. As has been stated, gray is a neutral quality. It obeys none of the laws of color, such as adaptation, afterimages, or induction. It may, however, be mixed with a color to form an intermediate quality. Let us, then, consider the modes of behavior of the colors. We shall see that even a simple visual sensation functions lawfully, or according to fixed modes.

Adaptation. If one fixates a color, the color immediately begins to adapt out, and the experience moves in the direction of brightness or neutral gray. In attempting to observe this law, the observer should make the fixation constant. The eyes should not be permitted to move from the area of color under observation. For illustration, place a small black dot as a fixation point in the center of a disk of blue

paper, and then fixate the dot for sixty seconds or longer. It will be noticed that after a few seconds the blue has become less blue; it then becomes a poor, washed-out blue; and, finally, after a few minutes, it will be noticed that the blue has entirely disappeared, leaving an area of gray or brightness. Adaptation occurs in general in this way when one fixates any primary or intermediate color. It is known, for instance, to chemists who, in tests involving colorimetry, caution students to observe for only a moment a substance under examination; after the substance has been fixated for several seconds, whatever color one might have seen at first will have vanished. One may observe the phenomenon when one gazes at a pennant in one's room, wears colored glasses, or sits for a while in a dark theatre. If one fixated the entire color pyramid, it would adapt out to a condition of gray.

Adaptation, under certain conditions, increases visual sensitivity. If one goes from bright daylight into a dark room, at first one is almost unable to see. The eyes, however, become increasingly sensitive until one is able to distinguish objects with reasonable ease. The change in sensitivity can also be noted when one passes from the dark room into sunlight, or when one removes a pair of colored glasses. The increase in sensitivity can be measured. Let us note one il-

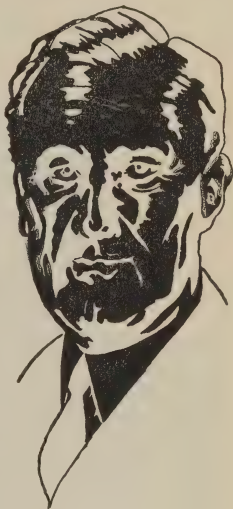


Fig. 10.—Adaptation Figure. (Fixate constantly a point near the center of the figure for 60 seconds. Note how the color becomes less saturated; then look steadily at a neutral surface.)

lustration. The weakest visible stimulus, as the faintest light that can be seen under normal conditions, is called the stimulus limen for light. When one is dark-adapted, as after having been in a darkroom for about thirty minutes, the stimulus limen for brightness may be reduced to $\frac{1}{10,000}$ of its

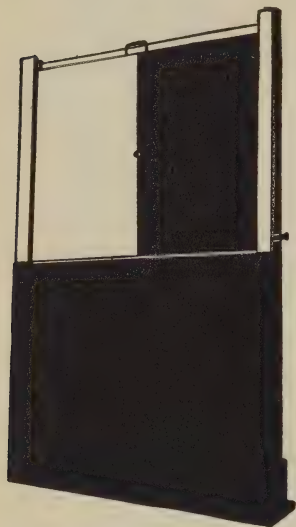


Fig. 11.—Adaptation Frame.

original value; that is, visual sensitivity may increase 10,000 times. Thus, sensitivity to colors is not constant, and, as we shall see in a later section, the retina itself is not uniformly sensitive. Moreover, variations in sensitivity are not uniform for all parts of the retina.

Induction. Whenever a neutral area, as a shadow or strip of gray, appears on a background of color, the neutral area becomes in quality the color complementary to the color of the background. Place

a narrow strip of gray paper across a sheet of blue paper and cover both with a sheet of tissue paper which is used to soften or eliminate the sharp lines. The gray strip will be seen as yellow. Likewise, project a green light upon a screen and then cause a shadow, as from a pointer, to fall upon the green area. The shadow will be seen as red or purple. Again, a shadow on a blue area is seen as yellow, on yellow it is seen as blue, and on red it is seen as green. One has probably noticed the color of shadows on the snow, the effects of lighting in stage scenery, and induced colors in

sunsets and on the surface of a lake. Induced color of unusually deep saturation may be had from projected lights.

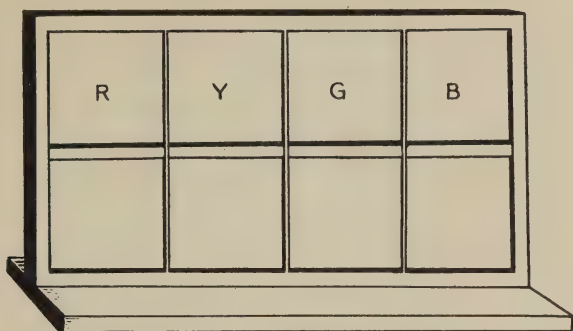
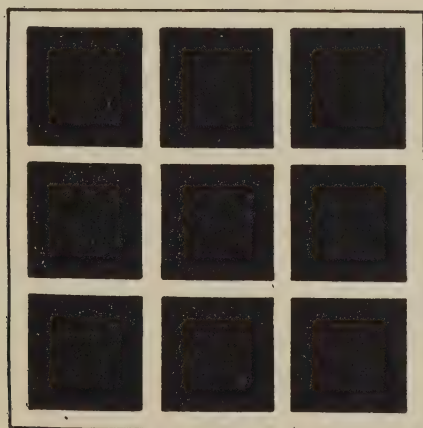


Fig. 12.—Induction Frame. (The narrow, horizontal strip of gray paper becomes in hue the complementary color of the background on which it rests.)

Contrast. When two complementary colors appear beside each other in the field of vision, they mutually enhance each other so that each becomes more deeply saturated in color than when each color is experienced alone. The phe-



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Fig. 13.—Schema to Show Induction and the Negative Afterimage.

nomenon is almost identical with that of induction; the primary difference is that in induction only one color need be employed to produce the second or induced color, while in contrast two colors are necessary. If, for illustration, red and green adjoin each other, both become more saturated. Likewise, if blue and yellow, or black and white appear near each other the amount of color in each member of the pair is increased. Furthermore, if red is adjacent to yellow, the red becomes bluish and the yellow becomes greenish. Thus, a mode of rivalry seems to exist, making a color become more colorful when in the presence of its complementary color. Contrast may readily be observed in the case of a white disk on a black background, a red rose surrounded by green foliage, or a blue and yellow ensemble.

Color mixture. Physically and psychologically, colors are constantly subjected to conditions of mixture. One knows from casual observation that pigments are mixed, colored disks are whirled, lights are intermingled and beams of different colored lights are projected upon the same surfaces. Moreover, the eyes shift swiftly from one color area to another, and light waves from different objects fall upon approximately identical parts of the retina. Then, what occurs psychologically when colors are mixed?

In the psychological laboratory colors are usually mixed in two ways, by disks and by projected lights. The colored disks are placed on a motor and revolved very rapidly. Since the retina functions chemically, when the disks are rotated there occurs the equivalent of a complete mixture of two or more colors on the retina. If colored lights are employed, filters are used so that a light of one hue is projected from one lantern and another light of a different hue from another

lantern, making the beams converge upon a gray screen. Thus, under such controlled conditions, two, three, or four of the primary colors may be projected upon the same area of a screen.

There are three laws of color mixture, as deduced from modes of mixture and results. They are called the first, the second, and the third laws, respectively.

The first law of color mixture is stated thus: Whenever two complementary colors are mixed in the proper proportions, they mutually cancel each other and the resulting experience is gray or brightness. Suppose one places red and green on a disk and causes the disk to revolve rapidly. The red and green will vanish, leaving an experience of gray or brightness. The same result is had when blue and yellow, or black and white are used. The law is, of course, operative generally. One simply does not observe a red-green, a blue-yellow, or a black-white. The complementary colors will not mix to produce an intermediate under any circumstances. The mixture of commercial pigments is no exception. Blue and yellow paints may, when mixed, give a green. But this is actually an evidence of the first law, for the green was an

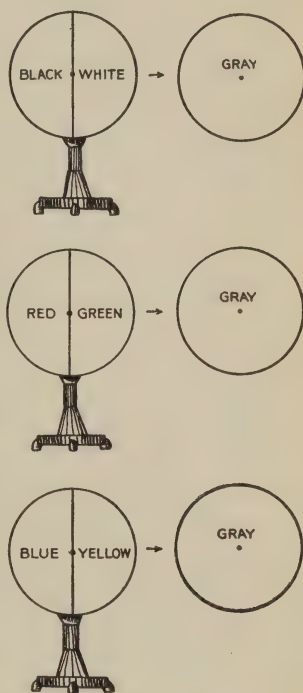


Fig. 14.—First Law of Color Mixture.

impurity that was covered up until the blue and yellow canceled each other.

The second law has to do with the mixture of noncomplementary colors. It is stated thus: When two noncomplementary colors are mixed in the proper proportions, the re-

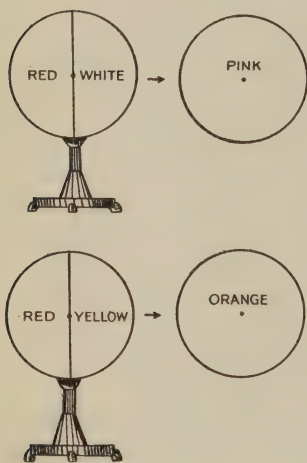


Fig. 15.—Second Law of Color Mixture.

sulting experience is an intermediate quality which resembles the two qualities mixed. For example, red and yellow, when mixed properly, give orange; white and red give pink; blue and red give violet; and black and gray give dark gray. Thus, any two noncomplementary qualities give an intermediate quality.

The third law refers to a mixture of all the visual qualities. It is as follows: If one mixes all of the colors in the right proportions, the resulting experience is gray or brightness.

For example, if one places on a disk the colors red, green, blue, yellow, black, and white in the right proportions, the colors will cancel each other, and the consequent experience will be gray or brightness.

Afterimages. The retinas, as has been stated, appear to function chemically. When light waves stimulate the retinas, changes in the visual purple associated with the microscopic nerve endings seem to occur. This activity does not stop immediately when the colored physical objects are removed, or when the physical stimuli cease to strike the retina.

There are, consequently, afterimage effects. These afterimages fall into two general types, the positive and the negative.

The positive afterimage may somewhat arbitrarily be classed in three groups, namely, the immediate, the prolonged, and the delayed. This classification is here made largely on the basis of the time of appearance and the variations that may occur in quality.

The immediate positive afterimage appears instantly after the visual stimulus has been removed.

In quality it is similar to the experience had when the physical stimulus was present. This type

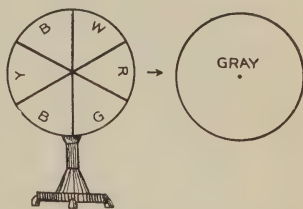


Fig. 16.—Third Law of Color Mixture.

of afterimage usually lasts for only a second or two, although when an intense stimulus, as a bright light, is used, it may last longer. This afterimage may be developed and observed by fixating a light globe, and then switching on the light for about five seconds. When the light is turned off, the sensation of light will continue for a short time. One may also suspend a light bulb before a piece of black velvet, switch the light on for a second, and then swiftly move the bulb to one side of the background. The observer will notice the light, filmy, semi-transparent image against the black of the velvet. In case of an intense stimulus of light, as a brilliant flash of lightning, the afterimage not only may last for several seconds, but also may be so extensive and well-outlined as to include a filmy, photographic view of a house or landscape such as was exposed to the observer.

The prolonged positive afterimage is obtained by the use

of an intermittent mode of visual stimulus. For example, one may fixate a light bulb, and then switch the light on for a moment's duration at intervals of about every two seconds until about fifteen exposures have been made. Or, better, one may sit about ten feet from an illuminated window, fixate some point on the window, and close the eyes and cover them with the hands to shut out the light; then we may remove the hands and look for a moment at the window, immediately closing and covering the eyes again. Repeat the exposure about fifteen times, and a gorgeous image of the window will appear and last for several minutes. The colors may vary so as to give several color qualities in sequence; their texture will be of a gorgeous velvety, filmy nature. If this experiment is tried immediately after one awakens in the morning, when the eyes are rested, the image will develop very easily.

The delayed positive afterimage is scarcely different from the prolonged. If, after a series of intermittent stimuli, the eyes are permitted to rest for several minutes or even for several hours, and are then subjected to a brief stimulus of light, the positive afterimage will appear. For example, if one has intermittent fixation of one's hand when one goes to bed, and then, several hours later, awakens and turns on the light for, say, a quarter of a second, a ghostly light gray hand may appear later in the dark visual field before one. The eyes should, however, be rested before the experiment is undertaken, and the hand should be brightly illuminated.

The negative afterimage. In quality, the negative afterimage is a hue complementary to the hue of the stimulus. If one fixates blue until an appreciable amount of adaptation has occurred, and then fixates a neutral area, a negative afterimage, yellow in hue, will appear. Then, when any

patch of color has been caused to disappear by adaptation, the color complementary to the color stimulus can be seen when the physical stimulus is removed.

Illustrations of the negative afterimage are too numerous for there to be need for one to mention more than a few cases. Wear a pair of blue glasses for a few minutes, remove them, and the field of vision, except the blues, will appear yellow. Fixate a disk of red until adaptation has occurred, remove the disk, and a disk of green will appear. A yellow stimulus gives a blue negative afterimage, a green gives a purple, a white gives a black, and conversely. All intermediate colors behave in the same way. In general, one may discover the quality of the negative afterimage by going from the color stimulus, as it appears on the color pyramid, through gray to the opposite side of the pyramid. For example, the complementary color of orange is a color lying midway between green and blue.

General facts related to visual qualities. As has been pointed out, there is an intimate relation between the physics, the physiology, and the psychology of vision. It is a well-known fact that physical stimuli, employed under different physiological conditions, produce different results. For instance, let the light stimulus fall upon the center of the retina, and then near the periphery; or decrease the intensity of the stimulus; or move the stimulus so that the image will pass from the periphery to the center of the retina. It will be observed that such variations result in different psychological effects. Some facts in this relation should be stated here.

Perimetry. The eye is a mobile organ, and one usually turns the eyes toward an object so the image falls upon the center of the retinas. Moreover, it rarely occurs to one that

the retina is not uniformly sensitive or uniform in its relation to colors. Only the exceptional person, for example,



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Fig. 17.—Automatic Recording Perimeter.

has ever discovered the blind-spot, or that in indirect vision objects are achromatic. In a type of experimental work which is usually designated as perimetry the retina is explored and mapped carefully, in order that the effects of various types of stimuli upon the different parts of the retina may be known. In this work a perimeter is used. With this instrument, stimuli of different qualities and sizes may be presented and a record automatically made. During

the experiment, the observer rests his chin upon the support at the front of the instrument, and gazes steadily at a fixation point at the center of the graduated arc. While one retina is under examination, the other eye is kept closed. A small disk of colored paper, fastened in the rider, is brought slowly from the end of the arc to the center. The observer reports when the stimulus enters the field of vision, describes it qualitatively, and then states any changes in quality that may occur as the stimulus passes from the periphery to the center of the field of vision. The experiment continues until

every part of the retina has been explored. What are some results?

It is discovered that there are three color zones, and also an outer peripheral area which gives the quality gray only. Let us note generally the nature and extent of these zones.

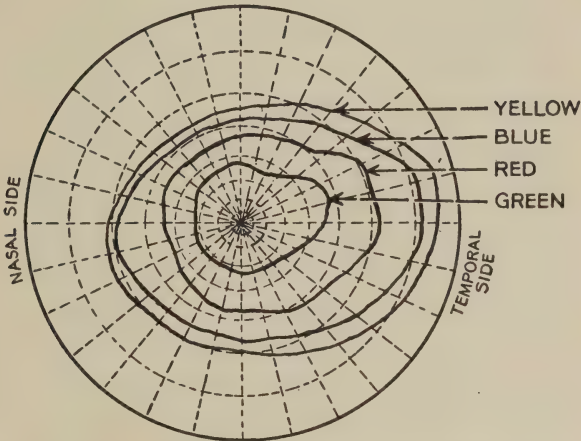


Fig. 18.—The Color Zones. (A map of the retina made by the use of the automatic recording perimeter. Colored papers do not give pure color stimuli; hence the difference in areas covered by complementary colors.)

Suppose a pure red stimulus is moved so that the image falls upon the retina near the edge and then slowly passes on to the center. The stimulus is seen first as gray; then it becomes red when the edge of a zone near the center is reached. There is, then, at the center of the retina a zone which responds to the spectral wave lengths of red. If a pure green is used, it will also be seen as gray until the stimulus reaches a zone also covering an area at the central part of the retina. When pure red and green stimuli, equal in size, tint, and chroma, are used, they appear as colors when the same area of the retina is stimulated. The *R*-zone and the *G*-zone are,

therefore, practically identical or coextensive. Blue and yellow are also seen as grays until the blue-yellow zone is reached. This zone, which also extends from the *fovea centralis* peripherally, is larger than the red-green zone. The black-white zone is the largest. The areas covered by the zones cannot be designated specifically, for variations in the size, the intensity, and the duration of a stimulus cause the zones to vary in extent. The size of the zones also differs with different people. The foregoing statements do not hold true when colored papers or other impure stimuli are used. A red paper, for example, when brought in from the periphery to the fovea, is first seen as a dark gray, then a black, then as blue or yellow, and finally as its true color. This stimulus is not pure red, and so gives black, blue, or yellow effect. In general, then, only the central area of the visual field is sensitive to colors, while the peripheral section gives the experience of grays only.

The fovea centralis. When one looks directly at an object, the image falls upon the center of the retina at the posterior pole of the eyeball. This part is called the *macula lutea*, or yellow spot. At its center is the *fovea centralis*, a slight depression, which is the part of the retina most sensitive to colors. If the image from the red stimulus object falls on the *fovea centralis*, the red experience is slightly more deeply saturated than it would be if the image fell elsewhere. This fact is also true of other colors. The *fovea centralis* is, however, not very sensitive to brightness. If, for instance, a faint image, as from a very weak light or a very dim star, falls upon this place it may not be seen. Early at evening, when the stars are beginning to appear, look monocularly, directly at a very faint star and it will likely vanish;

then look to one side of the star so the image will fall upon the peripheral retina, and the star will be seen clearly. As will be noted later, the *fovea centralis* has an abundance of cones, which are the sense organs of color, and very few rods, which are the sense organs of brightness.

The blind spot. At the posterior side of the retina, toward the inner or nasal side, is an irregularly shaped area called the optic disk, or the blind spot. This is the place where

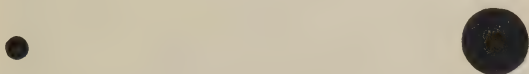


Fig. 19.—Schema for Locating the Blind Spot. (Hold the book eight inches from the eyes. Close the left eye and fixate the small black spot with the right eye. If necessary, rotate the book until the large spot vanishes.)

the optic nerve enters the retina and from which the nerves spread out to form the millions of sensitive nerve endings. The optic disk does not contain the specialized visual receptors, and it is not, therefore, a part of the true retina. One is consequently blind to stimuli that fall upon that area. The blind spot may easily be discovered and its limits determined by use of the perimeter. With this instrument, the stimulus object, say a black, is moved so that the image passes from the *fovea centralis* outward, and then from the periphery inward until the record is completed. If a perimeter is not available, the observer may fixate some point so as to keep the eye still, and then move a small color stimulus in the field of vision until the image falls on the inner nasal section of the retina when it will vanish visually. Then, too, with an ophthalmoscope one may see the optic disk in another person's eye. One rarely, if ever, notices the blind area of the field of vision, for binocular vision, the constant

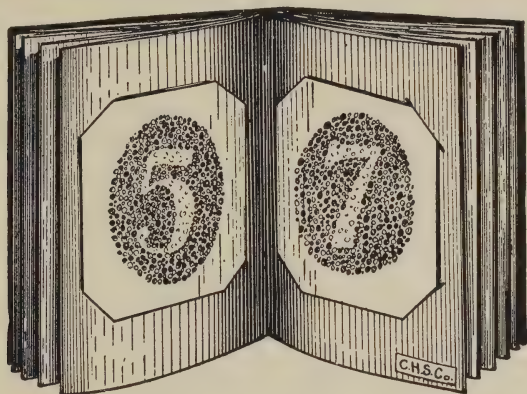
movement of the eyes, the tendency toward a sensory reduction of the area, and perception tend to eliminate it psychologically.

Twilight vision. We have noted the visual qualities which appear in normal daylight vision, and we have also stated how they behaved in time and in relation to each other. Now what occurs when one passes from daylight vision into night vision? There are several changes which must be stated.

The difference physically between daylight and twilight vision is to be found in the difference in the intensity of the physical stimuli. So long as the energy of the light waves, produced by natural or artificial light, is above a certain level, one experiences colors as they appear in normal daylight. When, however, the intensity is decreased, as by lowering the window shades or at the approach of twilight, the relative brightness and saturation change. The spectral colors afford a good illustration of what occurs. In daylight vision, yellow is the lightest color in tint, but, as the intensity is decreased, yellow ceases to be the lightest and green becomes the brightest color, a change called the Purkinje phenomenon. Then, in late twilight or night vision, the spectrum becomes a band of grays. If all the primary and intermediate qualities represented in the color pyramid could be brought into the field of vision at late twilight or at night they would appear as grays. All colors, therefore, become grays at night; a black becomes a dark gray, a white becomes a light gray, and a green is seen as a lighter gray than the other spectral colors.

There is one exception to the changes just indicated. The Purkinje phenomenon does not occur at the *fovea centralis*.

This section, unlike other parts of the retina, is designed for color stimuli only, and one is consequently blind at this point during night vision. As has been stated, if one fixates a faint star so that the small, faint image falls on the *fovea centralis*, the star will vanish; but it will appear clearly when the image falls on the peripheral retina.



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Fig. 20.—Ishihara's Color Perception Test. (The numerals are printed in colors which a person who is color weak or color-blind would find difficult, if not impossible, to see.)

Color blindness. As has been pointed out, in normal vision one is totally color blind to stimuli falling upon the outer zone of the retina, and also color blind when a condition of night vision exists. In addition, there are people who are partially or totally color blind. There are, in general, two types of abnormal color blindness, although many variations from these types may be found.

The partially color blind person sees pure red and pure green as gray. The solar spectrum would appear to him as yellow and blue and grays. The color pyramid would be seen as having gray substituted for the red and green areas.

His visual world is, then, one of black, white, blue, yellow and gray, and the thousands of intermediates.

One type of the partially color blind may also be sub-normal in his ability to discriminate between brightnesses. He is insensitive to brightness of the red end of the spectrum, and so the spectrum appears shorter. This type is called the protanope. Another type of the partially color blind, the deutanope, observes brightnesses as seen by the normal individual.

Partial color blindness was discovered by John Dalton, a chemist, in 1798. Being a Quaker, he was chided for wearing bright green socks. He began an investigation which showed not only his inability to see red and green as colors, but also that about 3 per cent of the male population and 0.1 per cent of the female population are partially color blind. Statistics now available are incomplete and unsatisfactory; relatively few cases have been examined carefully, and many people who are partially color blind are unaware of this abnormality. Such people have learned to call certain objects green and others red. They can in many cases also uncannily discriminate between colors in terms of touch experiences. Many tests for color blindness, including group and individual tests, have been devised. In every case effort has been made to eliminate brightness differences and any other factors which the subject might employ to pass or to fail to pass the test. The importance of this work is obvious in view of the responsibilities associated with marine, railway, and military service.

In general, partial color blindness is hereditary. It may, however, be acquired from accident or disease. Partial color blindness to blue and yellow occurs, but apparently it is always a result of a pathological condition. Hereditary partial

color blindness appears for the most part in males of alternate generations; it is transmitted from father through daughter to grandson.

Total color blindness, also usually a hereditary defect, is rare in occurrence and serious in nature. The totally color blind individual is unable to see red, green, blue, yellow, or any intermediates of these colors. He lives, visually, in a world of blacks, whites, and grays. In more than half of the cases, a condition of blindness exists at the *fovea centralis*. It appears that the *B-Y* and *R-G* zones are absent. A condition of twilight vision constantly exists. Extreme sensitivity to light and persistent nystagmus are typical. The totally color blind person frequently wears colored glasses or seeks a poorly lighted room in order to find relief from the discomfort provoked by relatively intense light. The nystagmus, a rolling, jerking movement of the eyes, is perhaps an effort to obtain clearer visual images, especially by turning the eyes so that the retinal image will not fall on the *fovea centralis* where a condition of blindness or semiblindness exists. The abnormality is relatively rare; only about one hundred cases have been recorded, although it is likely that the majority of the cases have never been reported.

Color weaknesses, involving weakness to two or more colors, is common. This is explained in terms of partially or poorly developed color zones. Different individuals differ widely in their observation of the saturation of colors, a fact which must be taken into consideration in experimental work with apparently normal observers.

Some physiological aspects of vision. The eye is the sense organ of vision. It is in this organ that rays of light, refracted from physical objects, set up nervous impulses which pass centrally over the optic nerve to the occipital lobes

of the cerebrum. The occipital cortex is the visual area of the brain. A brief examination of the anatomy and physiology of the eye should enable one to understand better the behavior of visual sensations and also perceptions associated with vision.

The gross anatomy of the eye. The structure of the eye is in many respects similar to that of a photographic camera.

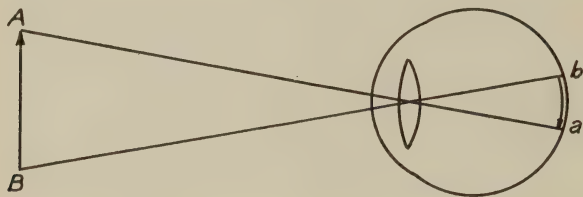


Fig. 21.—The Position of the Retinal Image.

The eyeball is a hollow sphere. It is approximately round, except at the cornea where a slight bulge occurs. The eyelids, when closed, serve as shutters which exclude light. Light enters the eye through the cornea and the pupil. The cornea is a transparent section of the sclera, that is, the outer coat of the eyeball; the pupil is a relatively small aperture at the center of the iris. The size of the pupil varies as the intensity of illumination changes, just as one adjusts the diaphragm in front of the shutter of a camera to admit more or less light into the camera. In a dark room the pupil is dilated while in bright sunlight it is contracted. Such changes are effected reflexly by the ciliary-sphincter muscles in the iris. One may observe variations in the pupils when drugs are applied to the eyes, or when a lighted match is moved toward and from the eyes.

The light next passes through the crystalline lens which is located just behind the iris. The lens is circular. It is suspended by radial fibers which are attached to the edge of the lens and extend to ciliary muscles attached to the anterior border of the choroid, which is the coat lying between

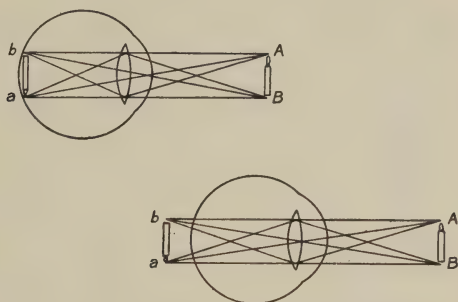


Fig. 22.—Normal and Abnormal Focus of Retinal Images. (If focus occurs as in the lower figure, the image will be blurred because of diffuse image on the retina.)

the sclera and the retina. The lens is plastic and adjustable. When the ciliary muscles are relaxed, the anterior side of the lens is almost flat, the posterior side curved. When one fixates a near object, the muscles contract and reduce the tension on the plastic lens, and the curvature of the lens consequently increases. In old age the muscles may assume a condition of somewhat permanent contraction and so cause one to become farsighted. The normal adjustment of the lens seems to occur when the object fixated varies in distance from a few inches up to about twenty feet from the observer. Finally, the light passes through the vitreous humor, a heavy, transparent fluid which fills the ocular cavity and holds the eyeball in shape, and strikes the retina.

The retina is the innermost of three coats which form the wall of the eyeball. It corresponds to the sensitive plate of the camera. The retina rests against the choroid, a brown

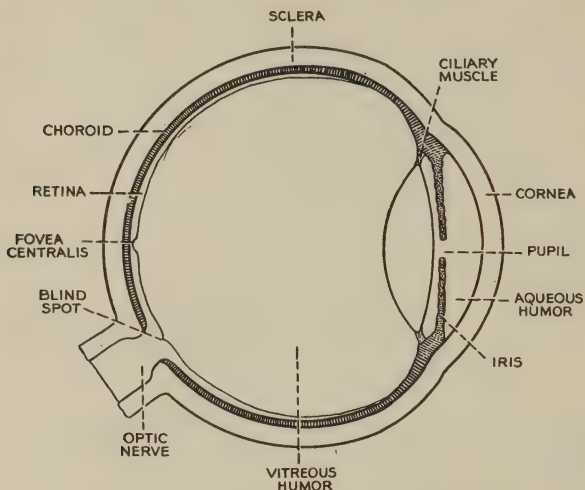


Fig. 23.—Cross Section of the Eyeball.

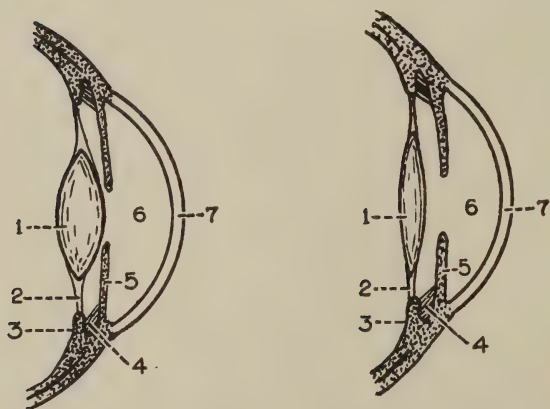
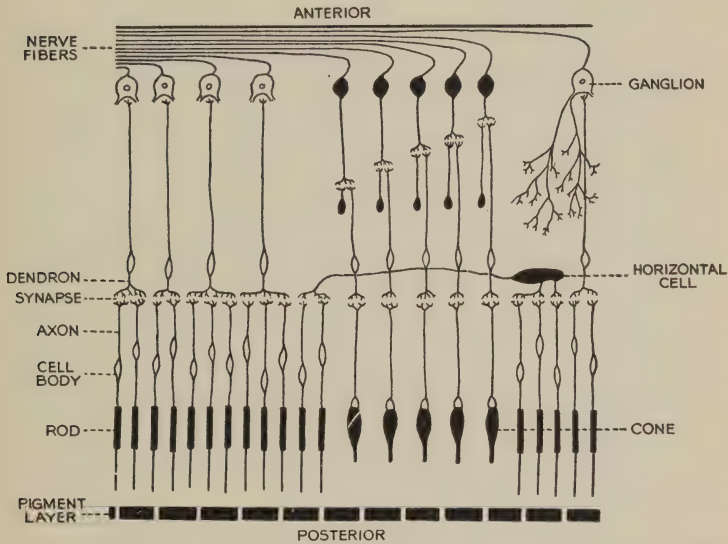


Fig. 24.—Sections of the Eyeball, Showing Adjustment of the Lens. (1, Crystalline lens; 2, suspensory ligament; 3, ciliary body; 4, ciliary muscle; 5, iris; 6, aqueous humor; 7, cornea. The lens becomes relatively thin when one fixates a distant object.)

membrane covering the interior of the eyeball, except at that area designated as the cornea. The choroid is abundantly supplied with blood vessels, and apparently is a medium of nourishment for the retina. The retina quickly recovers



After Howell

Fig. 25.—Diagrammatic View of the Retina. (Compare with Fig. 26. This arrangement of the structures, of course, is made for the sake of clearness.)

from effects of adaptation when in normal contact with the choroid; it does not recover when it is detached from it. The outer layer, or coat of the eyeball, is a tough, leathery membrane, the sclera. This membrane is opaque except at the cornea where it is transparent and permits light to enter. The optic nerve enters the eyeball just to the nasal side of the posterior pole. The nerve, which is said to be composed of more than one hundred thousand nerve fibres, passes

through the sclera and the choroid and spreads in a complex fan-shaped network over the anterior side of the retina.

The retina. The retina covers about two thirds of the inner posterior surface of the eyeball. It is a very complex structure consisting of the optic nerve fibers spreading over the anterior surface, commissural neurons associating these fibers with the rods and cones in the posterior area, and blood vessels which lie on the anterior side of the rods and cones.

The cones and rods. The end organs of vision are of two types, the cones and the rods. These are the specialized nerve endings that are stimulated by light and in which the nervous impulse originates. No visual impulse is produced in the optic nerve fibers or commissural fibers, although light entering the eye passes them before striking the cones and rods. The cones are shaped like cones or Indian clubs, and are generally thought to be receptors for color stimuli, and, in a large measure, are used for daylight vision. The *fovea centralis*, a very small section of the retina at the posterior pole of the eye, is composed of cones only, and is blind to faint stimuli of light. If one, at twilight, fixates a weak stimulus of brightness, as a pinhole of light or a faint star, so that the small image falls on the *fovea centralis*, the sensation will vanish. Totally color blind people are blind at the *fovea centralis*, and one cause of the nystagmus which they exhibit may be attributed to this defect. Moreover, it is believed that their eyes are deficient in cones. Furthermore, according to some authorities, the retinas of bats, owls, moles, and other nocturnal animals contain very few cones. It is estimated that the normal retina contains about seven million cones. The rods, the small rod-like structures, are generally thought to be the end organs of brightness. There

are approximately one hundred and thirty million rods in the retina. The color-blind peripheral areas of the retina, deficient in cones, are sensitive only to stimuli of brightness.

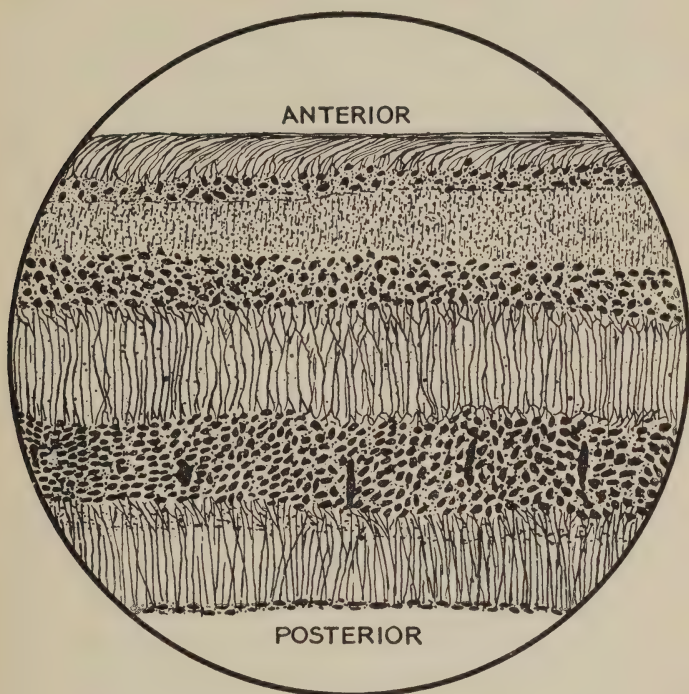


Fig. 26.—A Photomicrograph of the Retina.

The achromatic vision of the totally color blind individual seems to be effected solely by the rods and visual purple, a photochemical substance associated with the rods. Night-seeing animals likewise appear to depend upon the rods and the visual purple.

How is the change from physical vibration of the ether waves to the nervous impulses effected? Various theories are advanced to show how such conversion occurs, but no

theory seems to include all the facts. It is generally thought that the light waves excite the rods and cones by means of chemical changes effected in the rods and cones and in the photochemical substances associated with these end organs. Hering offers a simple theory based on the psychological visual phenomena. He assumes the existence in the retina of three types of photochemical substances, highly sensitive to light. These substances correspond to the pairs of complementary colors, namely, *Bk-W*, *B-Y*, and *R-G*, and also in extent in the retina to the three color zones outlined earlier in this chapter. The *Bk-W* substance occurs over a relatively large area, but not at the edge of the visual field; the *B-Y* substance covers a smaller section; while the *R-G* substance extends over a relatively small portion in the central section of the retina. These photochemical substances, like the sensitive coating of the film of a camera, are very unstable and respond to light stimuli. The *R-G* substance reacts to light waves corresponding to those of the red and green sections of the spectrum, and the *B-Y* to the blue and yellow sections, and *Bk-W* to all light stimuli above a minimum lower limit of intensity such as occurs in night vision. Each substance appears to consist of two complementary or antagonistic chemical characteristics. For illustration, when an observer fixates red, adaptation to that color suggests that the chemical substance corresponding to the red is bleached out or consumed, while the green negative afterimage seems to show that the green is either built up or given an opportunity to express itself. The first law of color mixture implies a condition of equilibrium of the *R-G* substance. Blue and yellow, and black and white behave toward each other in the same way exhibited by red and green. Gray, which is experienced when the retinas are not affected, is believed to

arise from molecular changes in the occipital cortex of the cerebrum.

This theory, therefore, offers an explanation of visual phenomena. The six primary colors, and the intermediates as well, are perhaps results of light stimuli which effect chemical changes in the retina. Gray appears to be caused by cortical activity only. Color mixture, adaptation, after-images, induction, and contrast are explained by these chemical activities. Total color blindness seems to be due to the absence of all three substances; and color weakness can be attributed to a deficiency of the *R-G* substance, or the substance associated with whatever colors are involved in the weakness.

The retinal image. It has been stated that the eye, with respect to its general structure, resembles a photographic camera. The size, shape and location of the retinal image are determined by the laws of optics. The size of the image depends upon the dimensions of the physical object and the distance of the object from the eye. Other things kept constant, the clearness and sharpness of outline of the image depends upon illumination. As has been noted, however, the retina is more sensitive to the outline of images in the region of the *fovea centralis* than it is in the peripheral areas. Like the photographic image on the ground glass plate of a camera, the retinal image is inverted. Moreover, it is obvious that the shape of the image is distorted when the image falls at some point on the side of the concave inner surface of the retina. If, for illustration, one fixates a statue, the image is inverted and is likely distorted in shape. How adjustment of position and shape occurs is a matter of perception and will be explained later. Numerous abnormalities of vision are caused by abnormally shaped eyeballs and

defective lens. Nearsightedness and astigmatism are familiar examples of numerous variations from the normal.

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CHAPTER IV

Audition

THE survey of the field of vision was designed to show the typical visual phenomena which occur when the sense organ of vision is stimulated. The world of audition, or sound, will likewise be examined in an effort to present a descriptive analysis of the realm of auditory sensations. In audition, as in other sense fields, the psychological descriptions must be made in terms of what one actually hears. Physical instruments must of necessity be used, and the physiology of the sense organ will be considered as a means of explanation of auditory experience, but the description of sounds themselves must be restricted to the states of consciousness as such. The difficulty of finding adequate terminology will be appreciated by any one who has tried to describe a tone in terms of its quality, intensity, size, texture, and other essential characteristics.

The primary auditory qualities. In vision there are seven primary qualities; in audition there are only two, noises and tones. It is very difficult to classify or describe these experiences satisfactorily, but we shall nevertheless undertake to describe them. We shall, moreover, specify their modes of behavior in time and in relation to each other.

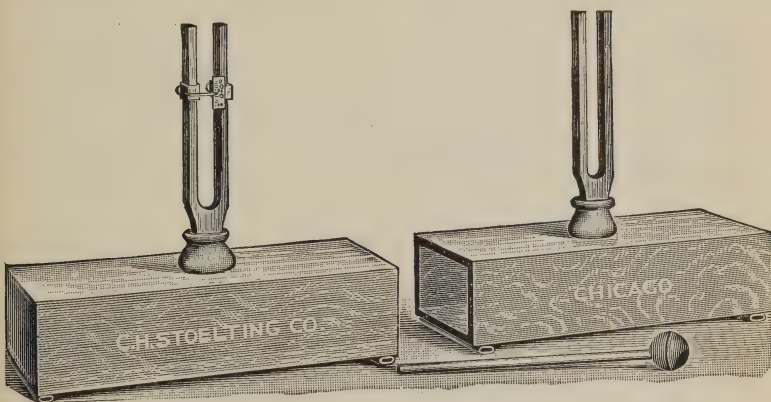
Noises are of two classes, the sudden and the continuative. Both types are drab, dull, rough, harsh, unstable, toneless,

voluminous experiences, indefinite in extent and irregular in texture. The sudden noise is a momentary, explosive experience. Familiar illustrations of sudden noise include the beat of a metronome, the click of the typewriter key against the paper, the thud of a ball against a glove, the explosion of a firecracker or a pistol, and the crash of thunder. Continuous noises are not abrupt and momentary, but are simple noise experiences which continue in time. Common experiences of this type are the sounds had from dragging a rug across the floor, scraping a stick on the pavement, the rustle of dry leaves or paper, the hiss of steam from an escape valve, the rattle of a kettle drum, the dash of the surf against the shore, and the roar of an elevated train. In many experiences thus produced the sensation may also be tonal. Experiences of noise are very frequent. One is constantly subjected to noise stimuli, especially if one lives in a city or near a thoroughfare. If one considers for a moment the amount of noise one hears within a day, one will understand what a large place noise occupies in one's consciousness.

Tones differ from each other widely with respect to their quality, their volume, their intensity, and their duration. In general, however, a pure tone, as heard at a given moment, may be defined as a relatively smooth, continuous, voluminous, tonal experience, generally uniform in texture and in density throughout.

Means of producing pure tones. One seldom hears a pure tone. The tones from an organ pipe, a piano string, a harp, a bell, or the vocal cords are complex sounds. Cheap tuning forks rarely produce pure tones. For the most part, those experiences usually called tones are composed of noise and several tones. For instance, from a sonometer or from

a piano string one can hear at least ten different tones in combination. Pure tones must be produced, therefore, by the use of special instruments. For the lower tones, tuning forks, weakly blown bottles, and weighted-wire forks may be used. To obtain high tones one uses small tuning forks, Quincke tubes, and the Galton whistle. The Galton whistle



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Fig. 27.—Tuning Forks on Resonance Boxes.

is adjustable to scale and may conveniently be made to produce pitch differences ranging from about 3,000 to more than 50,000 v.p.s. These carefully constructed instruments are used in psychological laboratories because, when properly operated, they give off only simple pendular vibration rates. This simple pendular or harmonic motion of the instrument produces a similar movement in the air and, eventually, in the mechanical sections of the ear. A tone thus produced is a pure tone physically, and it is heard as a simple, unanalyzable tonal process.

Range of audible tones. It is obvious that not all pendular vibrations produce sensations of tone. The pendulum of

a clock and the tines of a long weighted-wire fork move too slowly to produce tones. If a fork which vibrates at the rate of 6 v.p.s. is held near the ear, only experiences of noise, like sudden puffs of wind, are heard; and when the Galton



Fig. 28.—Weighted-Wire Forks.

whistle is set to vibrate 55,000 times per second, no tone is heard.

Then what are the lowest and the highest audible tones? The words low and high, in this relation, usually refer both to the quality of a tone and to the vibration rate per second of the physical instrument. The term pitch likewise has a dual meaning. The bass section of a piano is lower in pitch, that is, in quality and in vibrations per second, than the treble end. Likewise, the tuning fork c' is lower than c^2 and c^3 of the Galton whistle. The limits of audible tones will be stated, therefore, in terms of double vibrations per second.

The lowest vibration rate which produces tonal sensation

is 12 v.p.s. This fact is determined by experiment. A series of, say, thirty-five weighted-wire forks, ranging in vibration rate from 5 v.p.s. to 40 v.p.s., is used. The experimenter stands behind the observer and holds the vibrating fork near the observer's ear; the observer, who has his eyes closed and who does not know which fork is used, reports whether or not the experience is tonal. The experiment continues until each one of the forks, selected in chance order, is presented ten times. The record is then examined and the fork which was 50 per cent of the time reported as having been heard as tonal is specified as the lower limit of audible tones. Below this rate the experience resembles sudden noise or puffs of sound, weak and diffuse. The same type of experimental procedure is used to discover the upper limit of audible tones, except that one substitutes very small tuning forks or the Galton whistle for the weighted-wire forks. A rate of 50,000 v.p.s. is the maximum pitch number heard as tone. It must be stated that these limits vary widely with different people. For many people the lower limit is about 18 v.p.s., and the upper limit, say, 30,000 v.p.s., or less. There is also frequently a difference between the tonal limits of the ears of the same individual. Moreover, increasing age tends to shorten the range; the upper limit is often thus reduced to 30,000 v.p.s., or lower.



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Fig. 29.—Galton Whistle.

Distinguishable tonal qualities. The maximum number of audible tones, as has been stated, is approximately 50,000. Of this number many are so nearly alike in quality that they cannot be distinguished from each other. For illustration, no qualitative difference can be detected between 600 v.p.s. and 605 v.p.s., or between 2,000 v.p.s. and 2,010 v.p.s. Change the vibration rate of a Stern variator or of a Galton whistle slightly, and no difference in quality can be observed. Increase the difference, however, and a difference in the qualities can be detected. The number of just noticeable differences in quality is about 11,000. It may be said, then, that, just as one may distinguish some 35,000 different visual qualities, one may distinguish approximately 11,000 tonal qualities. These noticeable differences are worked out with the use of adjustable forks, Stern's variators, and the Galton whistle. Such types of apparatus are finely calibrated and fitted with sliding weights or micrometer screws, so that with them the entire range of audible tones may be examined.

Tonal volume. Auditory sensations are not usually regarded as tridimensional. The untrained individual rarely, if ever, thinks of tones as voluminous. Volume is, however, an intrinsic characteristic of tones. Listen to the tone coming from a tuning fork, c' , vibrating 256 v.p.s.; the tone is heard not as a point of sound, nor does it occupy two dimensions of space only; it is voluminous. Listen to the boom of a cannon, or to the roar of thunder; they are large, irrespective of any association that one may make with respect to their sources. Likewise, high tones, as the squeak of a mouse or the note of a canary, are inherently small; one simply cannot hear them otherwise than as small. Volume

varies with changes in pitch. Strike in quick succession the notes of a piano, going from bass to treble. Of course these are compound tones, but they offer a convenient means of showing the fact of volume. It will be noticed that the tones decrease in volume as one passes from bass to treble; those at the bass end of the scale are relatively large, while those arising from the treble sections are small. Of course a meter stick cannot be placed alongside sounds and exact measurements obtained; no such auditory meter stick has been invented. Nevertheless, one must undertake to describe sound as it is heard, and it is heard as tridimensional.

Tonality. The Pythagoreans, almost 2,500 years ago, discovered the tendency of tones to fall into octaves. As one passes over the musical scale, one finds that certain tones are more alike than others. The tone, c' , is in quality like c^2 , c^3 , and c^4 ; a' like a^2 , a^3 , and a^4 ; the primary difference between them is that of pitch. Such octave tonal resemblance may be illustrated by a spiral stairway; as one passes up or down the steps, one is at times at the same relative place, except one is higher or lower at one place than at another. Similarly a^2 is in pitch one octave higher than a' . The "tonal bell" has been designed as an illustration of the octave nature of tones. The position of a given tone, as a' , indicates its relative resemblance in quality to other tones and also the relative pitch of the tone. It is upon the principle of tonality that music is written and musical instruments played. The explanation of the resemblance of these tones seems to be found in the physics of tone. Tones which have the pitch ratios of 1:2; 1:3; 1:4, and so forth are very similar in quality. Thus, if C of a piano has a pitch frequency of 66 v.p.s., c has a frequency of 132 v.p.s., c' a frequency of 264 v.p.s., and so on.

Why the auditory resemblance occurs according to this relation is, however, unknown.

Vocality. It is now generally known that certain vibration frequencies, as produced by special apparatus, produce tones which resemble the sounds of letters of the alphabet. Thus, 131 v.p.s. resembles "m"; 262 v.p.s., "u" as in jute; 525 v.p.s., "o" as in hole; 1,050 v.p.s., "a" as in father; 2,100 v.p.s., "e" as in fete; 4,200 v.p.s., "i" as in ice; 8,400 v.p.s., "s"; 16,800 v.p.s., "f"; and 33,600 v.p.s., "ch." Such sounds may be had in pure form with the use of apparatus such as Stern's variator, but it is likely that overtones appear when the human voice or an amplifier is used. The mechanical equipment used to reproduce speech, as the phonograph, the radio, and robots, is constructed so as to give desired vibration frequencies. The meaning of such sounds, however, is of course a result of psychological association, and must not be considered intrinsic to the tones themselves.

Intensity of tones. As stated in the section devoted to volume, low tones appear relatively large, and high tones small. If intensity is thought of in terms of density and compactness, low tones are usually thin and diffuse, while high tones are dense, compact, and concentrated. The low tones of an organ seem large and diffuse; the lower tones of the Galton whistle are less compact than the higher tones derived from that instrument. Within limits, the higher tones also seem to have greater power of penetration; in this respect a soprano voice seems to be stronger than a bass voice, and the high tones of a violin may be heard above those of a cello.

Combinational tones. There are two types of combinational tones, namely, difference tones and summation tones.

The difference tone may be heard when one uses two generators having a minimum difference in vibration rates of about 35 v.p.s. It is better that the difference be 75 v.p.s., or more. Let us say the upper generator, "A," has a vibration rate of 1,200 per second, and the lower, "B," a rate of 1,050 per second. When these generators vibrate simultaneously, one may hear tone *A* arising from generator "A," and tone *B* from generator "B"; and one also may hear a third tone, *C*, which is a low tone whose pitch is 150 v.p.s., the difference between the rate of *A* and *B*. Under favorable circumstances the highly trained observer can hear as many as five difference tones arising from the combinations effected by tones *A* and *B* and by the difference tones themselves. The difference tones may be produced by such instruments as tuning forks, tuned steel bars, and double mill whistles. In general, the difference tone is a low, weak, diffuse tonal experience. It is believed that the majority of such tones are produced within the ear, and not by the vibrations of the physical instruments.

In addition to the difference tones, another tone, the summation tone, which we may designate as tone *X*, may be heard. It is a faint and somewhat shrill tone. It cannot be produced easily except by means of apparatus designed for the purpose. In pitch number, the tone is the equivalent of the sum of the frequencies of *A* and *B*, or 2,250 v.p.s.

Beating tones. As was observed in our study of combinational tones and tonality, tones exhibit interesting relations when they occur together in time. Some are consonant—that is, they harmonize—while others are dissonant—that is, they do not harmonize; and still others produce difference

and summation tones. Another type of auditory phenomenon is the beating tone which is a result of the blending of tones under certain conditions.

Suppose, for illustration, one has two tuning forks, "A" and "B," set to vibrate at the same rate, say, 256 v.p.s. If these two forks are made to vibrate simultaneously, only one tone is heard. This tone differs only in intensity from the

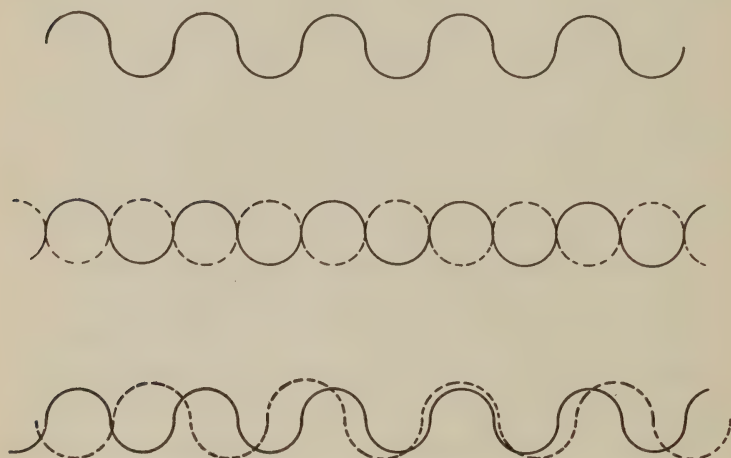


Fig. 30.—Diagrammatic Representation of Sound Waves.

tone produced by each fork when it alone vibrates. When the sound waves coincide with each other, the auditory sensation is more intense than if the pendular vibrations of only one fork occur. Now, suppose the rider on fork "B" is changed so that the vibration rate of that fork becomes higher than that of fork "A." When the forks are thus mistuned, within limits, a beating tone is heard.

The beating tone varies in several ways as the difference in vibration rate of the fork is increased gradually from a

slight difference to a difference of say, 30 v.p.s. When the difference in the pitch numbers is slight, that is, about $\frac{1}{4}$ v.p.s., the auditory experience seems to be a single tone that is smooth, and which becomes weak and strong, faint and loud, less intense and more intense. If the difference in pitch numbers of the forks is about 1 v.p.s., the tone subsides in intensity and becomes smoother in texture, and then surges to maximum intensity and becomes rougher and harsher as the intensity increases. As the difference in the vibration rates of the forks is increased still more, the beats become faster, with the intense part of the experience becoming relatively more conspicuous and the weak section so faint as to be detected with some difficulty. When the pitch difference is about 20 v.p.s., the beats become somewhat hard and rough; and, finally, with a difference of rate of about 30 v.p.s., a harsh rattle appears.

The location of the beating tone with reference to the generators changes when the pitch differences are changed. If the difference in the vibration rates is less than that required to produce a distinguishable difference in the quality of the tones, only one tone, the beating tone, is heard. This tone seems to hover between the generators. But when the pitch difference is increased, the two generating tones may be heard by a trained observer; the beating tone seems to lie between these two tones and move back and forth from one to the other.

Number of beats per second. The lowest rate of beats per second that may be heard is variously stated as one beat in 180 seconds, one beat in 24 seconds, and one beat in 8 seconds; the highest rate, as reported, varies from 33 beats to 250 beats in one second. When, however, the number per

second exceeds 35, the experience can scarcely be called a beating tone. The limits are not the same for all parts of the tonal scale; in general, the number heard per second is larger when the generating tones are selected from the higher regions of the tonal scale, as, for example, when two Galton whistles are used.

The number of beats per second is, from the point of view of physics, directly dependent upon the pitch differences of the two generators. Suppose two tuning forks, "A" and "B," have the vibration rate of 256 per second. If they are struck simultaneously, the sound wave phases will coincide and only one continuous tone, more intense than that produced by either fork alone, will be heard. If, however, a difference in pitch numbers of the forks is made, the number of beats per second is increased in direct proportion to the increase in pitch difference. Then, we have:

Fork "A"	Fork "B"	No. beats per sec.
256 v.p.s.....	256 v.p.s.....	0
256 "	257 "	1
256 "	258 "	2
256 "	259 "	3
256 "	276 "	20

This relation holds from the lower limit to the upper limit of audible beats, that is, from about one beat in 180 seconds to 33 beats in one second when these forks are used. When pitch difference is above 33 v.p.s., a harsh rattle appears.

Physical explanation of beating tones. The cause of beats is to be found in the physical coincidence and interference of the sound waves. If two forks are made to vibrate so that the phases are in exact coincidence, no beat will occur;

if they are caused to vibrate at the same intensity and so that the phases are precisely opposite each other, the interference will produce auditory silence. If, however, the pitch difference is such that the phases coincide, become opposite, and then again coincide, a beat is produced by the attendant increase, decrease, and increase in intensity of the physical stimulus. The number of beats per second is in direct proportion to the number of times the sound waves pass from phase coincidence to phase coincidence within that period of time.



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Fig. 31.—Differential Sonometer.

Overtones and timbre. We have noted that a pure or simple tone is produced by an instrument, such as a tuning fork or a Galton whistle, which gives one pendular vibration rate per second. Other instruments, as an organ pipe or a piano string, produce several different pendular vibration rates and, for the trained observer, several different tones having a definite relation in pitch number to each other. When, for illustration, one plucks a wire stretched between the two frets of a sonometer, the wire will vibrate as a series of simple harmonic frequencies known as partials. The first partial, or the fundamental, is the full vibration of the wire, the second partial is the vibration of the halves of the wire, the third partial the thirds, and so on. If the frequency of the fundamental is 100 v.p.s., that of the second, third,

fourth, and other higher partials will be multiples of 100, in the mathematical ratios 2:3:4, and so forth, to it, or 200 v.p.s., 300 v.p.s., 400 v.p.s., and so on. Now each one of these partials, up to about the 12th, produces a simple sensation or audible tone which may be heard by a highly trained observer. The tonal experience arising from the sonometer is,

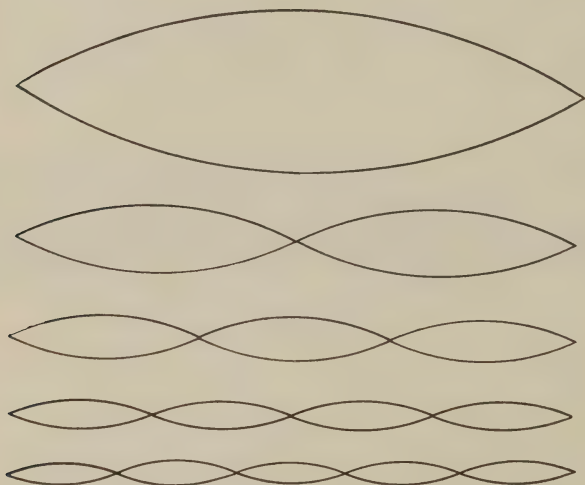


Fig. 32.—Schema Showing the Nature of Partials.

therefore, a complex or compound experience consisting of about twelve tones in harmonic relation to each other.

All musical instruments—the organ, the piano, the harp, the clarinet, the flute, the violin, the human vocal cords and their resonance chambers—are sources of compound auditory experiences. Many trained observers can analyze the compound tonal experiences into their constituent parts, thus hearing the partials as pure tones. The maximum number of partials heard by the practiced ear is about 12. The auditory analysis may be confirmed by a physical analysis made

by means of physical detectors or selectors which vibrate sympathetically with the several partials present in the physical compound. But what of the untrained observer and others who hear the tones in such combinations as one tone? It is believed by some psychologists that the experience is a simple one, due to complete fusion of the several partials. Yet, to these observers, the tone from the piano string and that from the organ pipe are different in color or timbre. It may, therefore, be argued that in such instances inability to analyze does not mean that the experience is a simple one.

Musical instruments differ from each other greatly in timbre or musical quality. The differences are caused by several factors, including the manner in which the vibrations are produced, the structure of the resonators or sounding boards, and the number and intensity of the overtones. For illustration, the piano string is struck by a felt hammer, the violin string is scraped by a bow, and air currents are blown over the mouth of the flute. The piano has a sounding board, the violin a resonance chamber, and the flute a tube-like body. Moreover, the size and shape of the instrument are designed to emphasize the fundamental and certain overtones; and, by virtue of this difference in intensity, the French horn, the trumpet, the clarinet, the trombone, the organ, and other wind instruments vary greatly from each other in timbre. Human voices are also notoriously different because of differences in the structure of and in the use made of the vocal cords and the resonance chambers of the throat, the nose and the mouth. Likewise, the tones of an organ are rich and full while those of a clarinet, limited and weak in overtones, are thin and nasal.

It seems that, in their behavior, tones and noises are in

many respects unlike visual sensations. In vision we noted the occurrence of such modes of behavior as adaptation, induction, and afterimages. But one does not find adaptation, induction, afterimages, and true contrast in audition. For illustration, one may listen to a tone for ten minutes and at the end of that time hear the tone as clearly as at the outset. Of course people who work in factories or other places, where tones and noises are constantly experienced, become so accustomed to such sounds that they do not notice them; but to become accustomed is not to become adapted. So-called positive afterimage effects are largely pressure experiences arising from the tympanic membrane and muscles of the middle ear. Contrast does not seem to exist in the world of sounds. Contrast in audition, as it is employed in the musical effects produced by orchestras, is very likely only meaning or psychological associations. The failure of such modes of behavior, as adaptation, to occur in audition is due to the fact that the sense organ of audition is mechanical, not chemical. When the physical stimulus is removed the ear ceases to function.

Theories of audition. The auditory nervous impulse, according to the best current theories, originates in that part of the ear which includes the organ of Corti and the basilar membrane. It then passes from the sensory end organs over the cochlear division of the eighth cranial nerve to the cerebrum. All other parts of the ear, except the semicircular canals, are merely contributory parts designed to transmit physical vibrations to the sensory nerve cells. The ear, for convenience of study, may be divided into three sections, namely, the external ear, the middle ear, and the inner ear.

The external ear. The external ear consists of two parts,

the pinna and the auditory meatus. Sound waves are caught by the pinna and directed inward through the auditory meatus to the tympanic membrane which lies obliquely across and closes the central end of the tube. The sound waves are thus made to strike the membrane and cause it to vibrate.

The middle ear. This section consists of several different structures. The tympanic membrane, which closes the central end of the auditory meatus and leads into the middle ear,

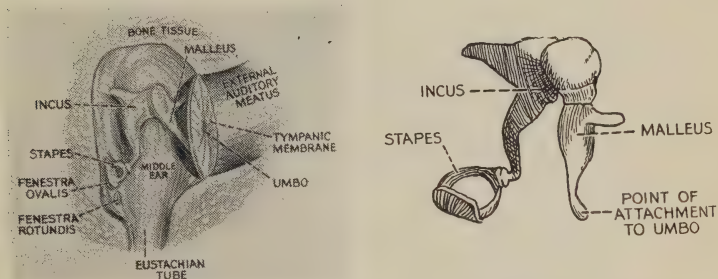


Fig. 33.—The Tympanic Membrane and the Auditory Ossicles.

is a thin and very sensitive membrane composed of a middle layer or network of circular and radial fibers, a coat of skin on the side toward the auditory meatus, and a layer of mucous membrane on the inner surface. A slight depression, the umbo, appears just below the center; the membrane, as seen from the external side, is slightly concave because of the pull of the tensor tympani on the membrane at this point. Its peculiar composition and shape are supposed to make the membrane an efficient mechanism for receiving and transmitting sound waves.

The ossicles, named in the order of their occurrence from the tympanic membrane centrally, are the malleus, the incus,

and the stapes. The handle of the incus is embedded in the tympanic membrane near the umbo, while the other end, the head, rests upon the incus. The incus, in its shape, somewhat resembles a molar tooth. The head of the stapes rests against a root-like process of the incus, while the base of the incus rests against the membrane of the oval window which leads into the inner ear. The stapes does not strike the oval window with piston-like movements, but rocks against it. The ossicles are held in place by ligaments attached to them and to the walls of the tympanic cavity, and they form an efficient means of transmitting vibrations from the tympanic membrane across the middle ear to the oval window of the cochlea.

Two small muscles, the tensor tympani and the stapedius, are found in the middle ear. One end of the tensor tympani is attached to the inner wall of the middle ear and the other to the handle of the malleus. When the muscle contracts, the tympanic membrane is pulled inward and adjusted for higher vibration frequencies. The strain felt in the ear when very high vibration rates are used probably arises from the effects of excessive contraction of this muscle. The stapedius is attached at one end to the wall of the tympanic cavity, and at the other to the neck of the stapes. It serves to pull the stapes laterally against the oval window and to adjust it and the membrane of the window for vibrations at high frequency.

The Eustachian tube is a canal which extends from the cavity of the middle ear to the pharynx. It serves as a drainage canal for the middle ear, and it is also a means of keeping equal the atmospheric pressure on the external and internal sides of the tympanic membrane. Unless precau-

tions are used, the pilot of an airplane may rupture the tympanic membrane during a power dive. If one descends from an upper floor to the ground floor of a skyscraper, or from the top of a mountain to a valley, one may notice pressure arising as a result of the unusual tension of the tympanic membrane. Under such circumstances the excess external pressure tends to push the membrane inward and prevent it from vibrating normally. If, however, one swallows, the

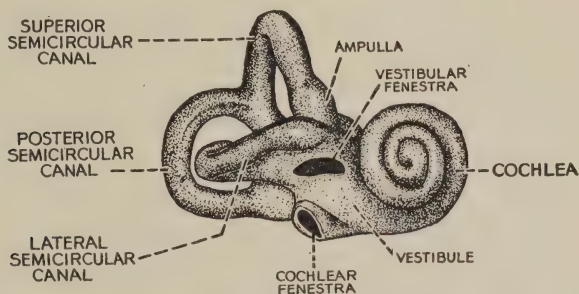


Fig. 34.—The Cochlea and the Semicircular Canals.

pharyngeal end of the tube, which usually is kept closed, will be opened and the pressure will become equalized.

The inner ear. This division, which includes the semicircular canals and the cochlea, is deeply embedded in the temporal bone. The semicircular canals have no direct relation to auditory sensations and, therefore, will not be discussed here.

In external appearance, the cochlea resembles a small snail shell. It is a tube, coiled two and one-half times, which contains the end organs of audition. If one could unroll the tube, one would find that it contains many subdivisions and numerous complex structures. First, a membrane and bony shelf divide the tube into two main divisions, the *scala ves-*

tibuli and the *scala tympani*. At the apex of the spiral tube, these two sections are connected by an opening, the helicotrema. The basal end of the *scala vestibuli* is closed by the membrane of the oval window against which the stapes rests; the basal end of the *scala tympani* is closed by the membrane of the round window which is located near the oval window. The tube is filled with perilymph, a liquid which is continuous from the oval window to the round window. Thus,

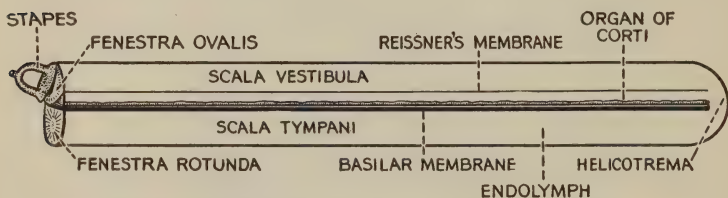


Fig. 35.—Cross Section of the Cochlea, Unrolled.

when the stapes causes the oval window to move back and forth, the perilymph vibrates according to the principle of hydraulic movement. Reissner's membrane divides the *scala vestibuli* into two parts, thus forming a small triangular tube, the cochlear duct, which extends from the oval window to the helicotrema. Within this duct are the basilar membrane, the organ of Corti, and the tectorial membrane.

The basilar membrane lies between the *scala tympani* and the cochlear duct. Its fibers extend from the bony shelf on one side to a ligament structure on the wall of the cochlear cavity. The basilar membrane is somewhat triangularly shaped; its fibers, arranged like the strings of a harp, are longer near the helicotrema than they are in the section near the oval window. The ratio of difference in length of the transverse fibers of this long, narrow, triangular band is va-

riously estimated as 1:12, 12:30, and 13:23. The membrane contains about 20,000 transverse fibers, arranged, as has been stated, like the strings of a piano or of a harp.

The organ of Corti is within the cochlear duct and rests upon the basilar membrane. It is a small, ridge-like struc-

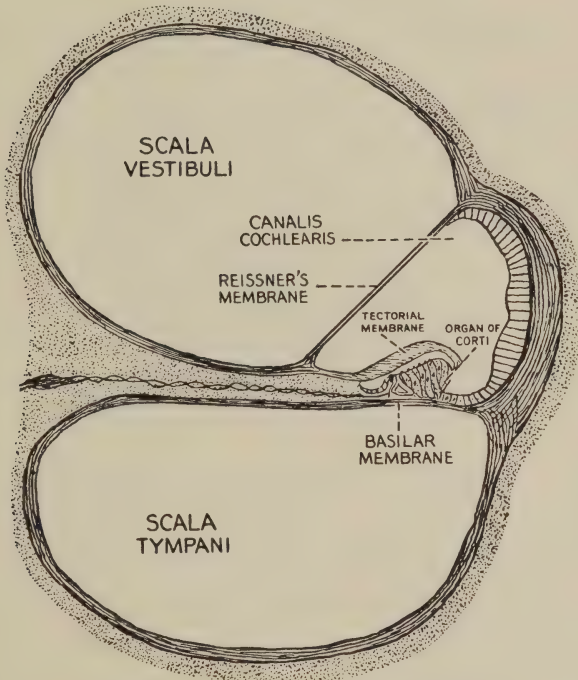
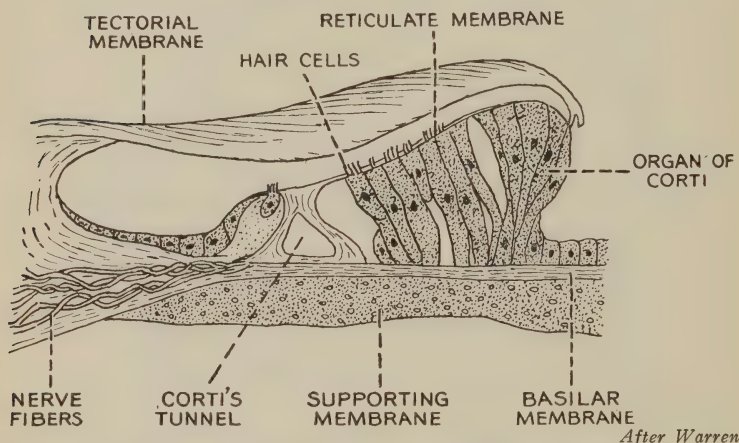


Fig. 36.—Cross Section of the Cochlea.

ture which extends from a point near the oval window to the helicotrema, and consists primarily of columnar nerve cells. The structure is covered by a thin membrane, the reticulate membrane. The peripheral ends of the columnar cells project through the reticulate membrane as hair-like nerve endings or cilia. These hair-like nerve endings occur in

bunches of about 20 each; there are altogether about 16,000 of them. The tectorial membrane is a long, narrow strip, varying in width and thickness, which extends from the bony shelf out over the organ of Corti and rests upon or very close to the hair cells which project through the reticulate membrane.

The inaccessibility of the cochlea in the living organism



After Warren

Fig. 37.—The Organ of Corti and Associated Structures.

makes it impossible to know precisely how it functions. There are, however, several theories of audition. One of the earliest and most widely accepted is that of Helmholtz. This theory assumes that the fibers of the basilar membrane are the end organs where the auditory nervous impulses originate. There are approximately 20,000 of these fibers. In length they differ as do the strings of a harp, with the shorter ones near the oval window and the longer near the helicotrema. It may be that those nearer the oval window are kept more taut by the ligament to which they are at-

tached than are those near the helicotrema. Helmholtz assumes that these fibers act as resonators which vibrate according to the principle of sympathetic vibrations. If two tuning forks have the same pitch number, when one vibrates the other will vibrate sympathetically with it; likewise, a violin may respond sympathetically to the partials of a piano with which it is tuned. Helmholtz assumed, therefore, that when a tuning fork vibrates 256 v.p.s., for example, one hears the tone because a section of the basilar membrane vibrates sympathetically with the tuning fork. Likewise, one hears overtones, as from a piano string, because of the sympathetic response of sections of the membrane corresponding in pitch number to the partials of the string. Noise results from either a momentary disturbance of one or several areas of the membrane, or from prolonged nonpendular vibrations of one or more sections. A beating tone is explained by the overlapping of the movements of two adjacent strips of vibrating fibers.

It has been argued that the fibers—ranging in length from 0.041 mm to 0.49 mm—are too minute, too few in number, and too definitely embedded in the adjacent cells to vibrate effectively or to be able to give the total range of almost 50,000 audible tones. In support of the Helmholtz theory, one may list the fact of sympathetic vibration, the difference in length of fibers, the apparent difference in tension, the weighting of some of the fibers by the arches of Corti, and a pathological condition known as “tonal islands.” In a case of tonal islands, the patient may hear normally certain parts of the tonal scale and be unable to hear other parts. For illustration, he may hear sounds having pitch numbers of from 100 v.p.s. to 500 v.p.s., and from 1500 v.p.s. to 4000 v.p.s., and

be deaf to the remainder of the tonal scale. The areas of deafness are thought to be caused by a pathological condition of the fibers corresponding to the pitch numbers involved.

Wrightson and Keith assume that the hair cells which protrude through the reticulate membrane of the organ of Corti are the end organs of audition. The tectorial membrane is a long band resting against or very near these hair-like peripheral ends of the hair cells. When, therefore, the perilymph is displaced by movements of the oval window, the wave moves forward and also downward through Reissner's membrane into the cochlear duct and causes sections of the tectorial membrane to press upon and slide back and forth over the upper surface of the organ of Corti. The movements may be rhythmical or not; rhythmical movements produce sensations of tone, while abrupt or nonpendular movements produce sensations of noise. Differences in intensity of the movements cause differences in auditory intensity in proportion to the stress upon the cilia as they are bent back and forth.

Others, including Ebner and Hardesty, suggest that the tectorial membrane contains the sensory nerve endings. They point to the freedom of the membrane to vibrate, its increase in width from the oval window to the helicotrema, and its variations in thickness. On account of the impossibility of observing the cochlea of the human ear, it is doubtful that this theory, or any other, may soon become more than theory.

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CHAPTER V

Taste

THE third field of sensory experience which we shall examine is that of taste, or gustatory sensations. The problem here, as in vision and in audition, consists of a statement of the typical gustatory qualities, their behavior in time, and their relation to each other. It will be noted that the field is a restricted one and that the taste sensations have rather definite modes of behavior, although many characteristics of taste are not as clear as are those of vision.

The confusion of taste with smell and touch. In experimental work in the field of taste, it is necessary to avoid confusing taste sensations with those of touch and smell. Ordinarily one makes no such distinction. For instance, one remarks that the taste of the coffee is excellent. At a dinner one hears many comments about the quality of the food served, and almost invariably the compliments are expressed in the language of taste. But if one analyzes the so-called taste experiences, one will discover that the "taste" of the fruit cocktail, the soup, the meats and vegetables, the salads, the ice cream, the nuts, and the coffee is in reality taste and touch—pressure, warmth, cold, and so on—and smell—fruity, almond, coffee, and the like. It is easily understood why such confusion occurs. The sense organs of taste, touch, and smell here involved are located in such close

proximity to one another that usually, especially in the case of taste, all three are stimulated simultaneously. It is, moreover, almost impossible for an untrained observer to separate the different sensory qualities. End organs of taste and touch are to be found in the upper surface of the tongue. When one conveys food to the mouth, air currents pass from the substance into the nostrils; and air currents also pass externally from the oral cavity through the nasal pharynges and thus may stimulate the sense organ of smell. One who suffered a severe nasal injury reported quite naturally a deficiency in taste. It is in this way, therefore, that when one drinks hot coffee one may have simultaneously the touch experiences of warmth and pressure, the fragrant odor of coffee, and the taste of bitter. Chilled, unsweetened lemonade likewise arouses the same touch quality of cold that one experiences on the back of the hand, the odor called fruity, and the taste quality sour. One who suffers from a bad cold or nasal catarrh, which frequently causes the olfactory sense organ to be temporarily covered with mucous secretion, often complains that foods do not taste right. If the nostrils are closed, castor oil is not so offensive in taste.

In experimental laboratories it has been proved that an observer, when his nostrils are packed with cotton wool to prevent the passage of air currents, cannot distinguish between the taste of raw apple and that of raw potato, or the taste of beef tea and that of a weak salt solution similar in touch quality. Suppose, for illustration, the experimenter prepares fifty small cubes of apple and fifty of potato, all similar in size, texture, temperature, and moisture; then, having excluded the sense of smell, let the cubes be placed in chance sequence one at a time on the upper surface of the tongue.

The reports will show that the observer will mistake the apple for the potato, and vice versa, about 50 per cent of the time. From this and other experiments it appears that the field of taste is not only easily and frequently confused with other sense fields, but also that it is relatively poverty stricken in sensory qualities.

The taste qualities. It is impossible to offer here a final statement about the total number and the types of the taste qualities. The number of possible taste substances in the world is enormous. One has only to consider for a moment the number of chemical elements and compounds in soluble, liquid, vaporous, or gaseous form to realize that the number of taste stimuli is almost unlimited. Besides, some substances, as potassium cyanide, are so poisonous as to forbid their use experimentally.

It appears, however, that there are four primary taste qualities, namely, salt, sour, sweet and bitter. There are, of course, many stimulus substances that produce the sensory quality sweet, and likewise there are many so-called sour, or bitter, or salt substances. Just as cane sugar, maple syrup and honey are sweet, so lemon juice, grapefruit juice and hydrochloric acid are sour. To avoid confusion, experimenters have, therefore, chosen cane sugar as the taste stimulus for sweet, sodium chloride for salt, quinine for bitter, and hydrochloric acid for sour.

There are qualitative series in taste, composed of terminal qualities and their intermediates, similar to the series discovered in vision. For illustration, the taste of bicarbonate of soda, NaHCO_3 , resembles salt and sour; that of potassium bromide, KBr , resembles salt and bitter; and that of acetate of lead, $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, resembles sweet and sour. The pri-

mary taste qualities and their intermediates may be arranged in the form of a tetrahedron. The planes of this figure are solid because there are qualities which resemble three of the terminals. There is, however, nothing in taste which resembles the visual sensation of gray, for in case of complete adaptation, or when the end organs of taste are not stimulated, the observer has no taste experience whatever.

The behavior of taste qualities. In this sense field adaptation occurs, but less rapidly and completely than in vision, in smell, or in some experiences of touch. Weak stimuli adapt out rather quickly, but it is difficult to become completely adapted to in-

tense stimuli. A weak stimulus of sweet, salt, or sour adapts out within a few minutes; a saturated salt solution, however, will not adapt out completely in several hours. The bitter of quinine, perhaps because of the high sensitivity to that taste substance, will persist for a long time. When fruit and other foods are at first slightly too sour or too salt, adaptation soon reduces the intensity to a desirable level, although under such conditions adaptation probably does not become complete.

Contrast may easily be observed. But here again no satisfactory generalization can be made. No satisfactory arrangement of complementary or antagonistic qualities, such as we have in vision, can be had. Salt, sour, and sweet show contrast effects under certain conditions; bitter seems to re-

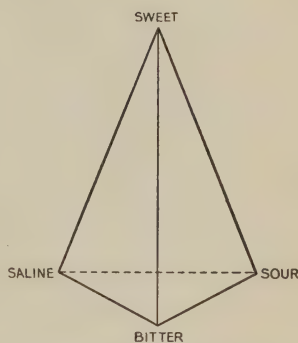


Fig. 38.—The Taste Tetrahedron.

fuse to enter into any such relation with any other quality. If one, with the use of medicine droppers, places simultaneously a drop of lemon juice on one edge of the tongue and a drop of a very weak sweet solution on the other edge, the intensity of the sweet will be increased. Likewise, when salt and sweet, or sour and salt, are thus experienced simultaneously, they produce the phenomenon of contrast. It must be remembered that in all such illustrations, the taste substances are applied to different areas of the tongue and are thus not mixed. If the substances were mixed or applied to the same group of taste buds, perhaps cancellation might be effected. There is no danger of actual mixture when, for example, one eats grapefruit and then pancakes and syrup, or vice versa, and thereby obtains pronounced contrast effects.

Cancellation seems to occur also within limited conditions, and not generally. Here again no fixed rule or classification of qualities can be made. Weak stimuli, when mixed in the right proportions, cancel each other; intense stimuli do not. Salt seems to cancel the bitter of grapefruit; sugar cancels the sour of an orange and the bitter of coffee; salt cancels the sour of lemon. Complete cancellation, like complete adaptation to intense stimuli, is very rare. When it occurs, the result is not a neutral experience or a quality analogous to gray; it is no experience at all. Usually, instead of complete cancellation, one quality obscures the other. When stimuli of high intensities are used, cancellation does not occur and the components of the complex experience may easily be identified. Blends or fusions are frequently observed. The sweet and the bitter of plain chocolate, the sour and the sweet of salads and the salt and the

sour of pickles may be observed. Some of us enjoy mixed foods because of the wide variety of qualities we can discover in them. But it must be remembered that smell and touch usually play an important rôle in such conditions.

The existence of afterimages has not been determined. There may be positive afterimages, and there is some evidence of negative afterimages. But it may be that the so-called aftereffects are produced by taste substances that have not been removed from the taste bud, or by chemical changes in the taste substances.

Theories of taste. The sense organ of taste does not consist of one sensitive area only in which the peripheral receptors are packed together, as is the case with the rods and cones of the retina and the fibers of the basilar membrane. The taste buds, in which the gustatory stimulation normally occurs, are found in widely distributed parts of the oral cavity, including the dorsal surface of the tongue, the mucous membrane of the cheeks, the soft palate, the larynx, the uvula, and the epiglottis. The distribution of the taste buds varies with age; as one passes from childhood to adulthood, the taste buds in the lining of the cheeks and the central area of the tongue decrease in number or vanish. The buds on the tongue are for the most part located in the circumvallate papillae in the trench-like depressions of the upper posterior surface of the tongue, in the fungiform papillae at the tip and anterior sides, and in the regio foliata of the posterior sides. There may be few or many taste buds in one papilla. As a rule, the number in a circumvallate papilla is much larger than that in the fungiform papilla.

The taste buds are somewhat elongated, bud-shaped or bulb-shaped structures, about 0.04 mm by 0.06 mm in size.

Within the bud are supporting columnar cells, at the center of which is a group of slender, rod-like cells which end peripherally in a hair-like process extending into the taste pore. Sapid substances stimulate these hair-like processes and thus produce nervous impulses which pass centrally over the fifth cranial nerve.

The theory of special functions. The theory of specific energies is said to find support in the field of taste. This

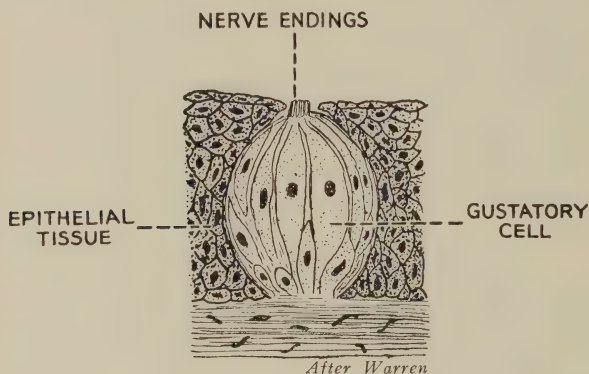


Fig. 39.—The Taste Bud.

theory claims that one type of end organ, when stimulated, may arouse only one type of sensory experience. It is believed that a given type of taste bud, when stimulated, will produce one taste quality only. It appears that functionally there are four types of taste buds—salt, sour, sweet, bitter—which are distributed irregularly among the papillae and over the surface of the tongue. It seems that some papillae contain only one type, as sour, and give sensation of that quality only, while other papillae contain two, or three or even all four types and produce as many different taste qualities when stimulated by different chemical substances. In

general, it may be said that the bitter type is more prevalent at the back of the tongue, the sweet at the tip, and the sour on the sides, while the salt is uniformly distributed over the areas sensitive to taste. This difference in distribution of the types of taste buds is offered to explain why the taste of quinine, for example, is more pronounced when the stimulus is applied to the back of the tongue. Likewise, it shows why the tip of the tongue responds more freely to cane sugar and the sides to lemon juice.

The theory of specific functions may also be offered as an explanation of the occurrence of simultaneous and successive contrasts. The existence of different types of end organs, each type reacting in its specific manner and producing its particular taste quality, may be the cause of contrast effects associated with adaptation, and explain phenomena that resemble negative afterimages. It must be remembered, however, that a given type is not confined to one area only. Quinine will arouse the same quality, bitter, whether applied to the tip, the edge, or the base of the tongue or to the soft palate. It must also be noted that the threshold of sensitivity is lower for some gustatory substances than for others, and in some sensitive areas than in others. In general, one is much more sensitive to quinine than to hydrochloric acid, to hydrochloric acid than to cane sugar, and to cane sugar than to sodium chloride. It would seem, then, that if the doctrine of specific energies applies to taste, the difference in sensitivity as it exists for different areas depends upon the relative number of taste buds of a given type in a given place. The fact that electrical stimulation of the chorda tympani produces sensations of taste has been offered as evidence against the theory of specific functions of taste buds. Such

abnormal sensations may, however, involve projection or reference, such as may occur when the nerves in the stump of an amputated arm are stimulated and the pain is felt as though it were in the fingers.

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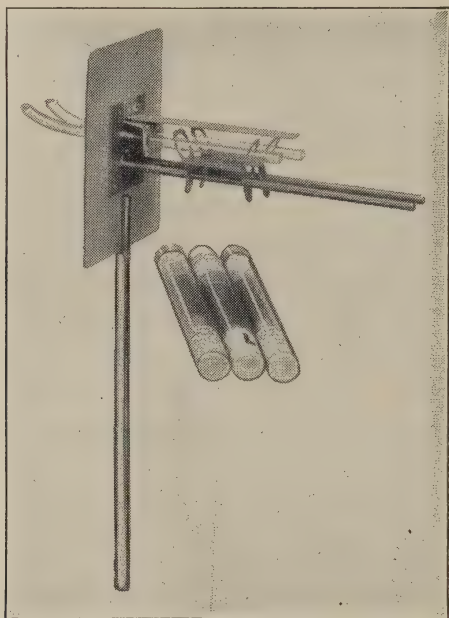
CHAPTER VI

Smell

IN SENSITIVITY, the olfactory sense is one of the most acute sensory fields. It is also one of the richest in qualities of sensory processes. These facts are not generally known, for, as we have seen, taste seems to appropriate to itself the larger portion of olfactory sensations. Moreover, since man is no longer under the necessity of using smell to protect himself from noxious foods and other dangerous things, he does not rely upon this sense or develop its use to any great extent. For instance, primitive man probably depended upon the sense of smell to safeguard himself from putrid meat, whereas now pure food laws make such precautions unnecessary.

Experimental methods in the field of smell. In experimental investigations, confusion of smell with taste and touch must be avoided. If taste substances are left in the mouth, such substitution and confusion of experiences are likely to be made. It is also necessary to avoid, in so far as possible, touch experiences that are produced by many odoriferous substances. It is well known that some physical stimuli, as bromides, irritate the mucous membranes of the nostrils. The odor of chlorine gas is usually attended by pain in the nose, and pepper may be so irritating as to cause violent sneezing.

The experimental apparatus. In experimental work the olfactometer, an instrument devised by Zwaardemaker, is used to control and measure the smell stimuli. There are two types of olfactometers, the one devised for the use of solid stimulus substances and the other for the examination



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Fig. 40.—Zwaardemaker's Olfactometer for Solid Smell Substances.

of liquids. The apparatus with which dry substances are tested consists of a screen through which extends a hollow glass tube, graduated in fractions of centimeters at one end and curved at the other end to fit into the nostril. An olfactory cylinder, a cylinder of solid smell substance covered on the outside with glass, is placed on the graduated glass tube. If the smell cylinder extends beyond the end of the

graduated tube, it is obvious that air currents will be drawn by the exposed interior of the olfactory substance; and the further out the cylinder extends the larger will be the amount of surface of the olfactory substance exposed. Cylinders containing cedarwood, gum camphor, asafoetida, India rub-

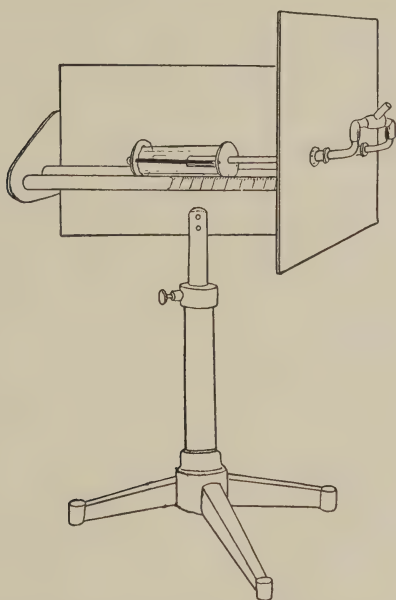


Fig. 41.—Zwaardemaker's Olfactometer for Liquid Smell Substances.

ber, leather, or other substances may be had. The apparatus for wet stimuli is similar in construction, except that it has a container for liquids which has an adjustable shutter permitting a given amount of the surface of the liquid to be exposed to the inhaled air currents drawn in over the exposed area. Both types of apparatus are constructed so as to use one nostril or both, and to stimulate the nostrils with the same or with different olfactory substances.

The olfactory stimuli. The olfactory substances are conveyed into the nostrils by the air currents of inhalation and exhalation. Since the stimuli are suspended in air, they must be in gaseous or vaporous form. Odoriferous bodies, whether solid or liquid, emit minute particles which affect chemically the end organs of smell. Nonvolatile substances are inodorous. Nor are all volatile materials odorous, for it seems that only certain types of chemical compounds react upon the end organs in such a way as to produce sensations of smell. The chemical elements are for the most part, if not all, inodorous. The total number of smell substances is unknown. Henning worked out more than four hundred, but one has only to think of the vast number of chemical compounds and the odors from foods, gardens, woods, and tropical regions to realize the almost unlimited wealth of materials that seem to be available in the field of smell.

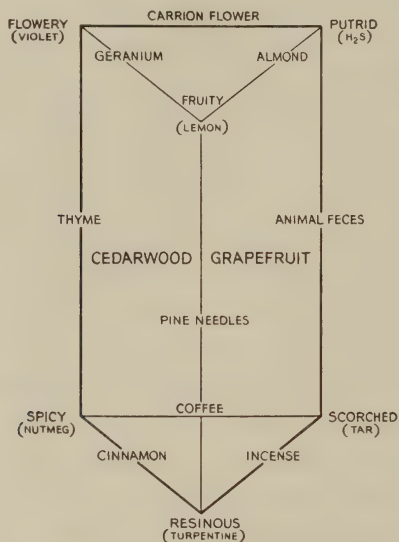
The smell qualities. No final list of primary qualities has been made. Classifications have been made in terms of pleasant and unpleasant or desirable and objectionable odors, as well as by designations of the smell substances themselves. One of the best of the earlier classifications is that made by Zwaardemaker, following Linnaeus and others. It consists of the following odors: ethereal, aromatic, fragrant, ambrosiac, garlic, burned, hircine, foul, and nauseous. But this list contains several types, as the foul and nauseous, which appear to include more than pure olfactory sensations. Nausea, as other experiences, may embrace not only odor but also a vast number of other psychological reactions. This list, it would seem, cannot be accepted as satisfactory.

The primary smell qualities. In more recent years, Henning did extensive experimentation in which the observers

were unaware of the smell substances used and were asked to report the quality of the odor experienced. He, on the basis of this work, reduced the list to six primary smell qualities. It is now believed that the primary qualities are: flowery, fruity, putrid, scorched, resinous, and spicy. In order to specify the particular quality meant in each case, Henning named the odoriferous substance which most closely corresponds to the odor. These identifying substances are: flowery, violet; fruity, lemon; putrid, hydrogen sulphide; scorched, tar; resinous, turpentine; spicy, nutmeg. Qualitatively, these six odors are considered essentially unlike each other; and every one of the many thousands of other olfactory qualities resembles two or more of these six and thus is classed as intermediate.

The smell prism. If we arrange the primary qualities and the intermediates on a prism according to their actual relations to each other, we shall have the smell prism. It must be noted that there are qualities which resemble two primaries. For illustration, geranium falls between flowery and fruity, almond between fruity and putrid, carrion flower between flowery and putrid, pine needles between fruity and resinous, and coffee between spicy and scorched. There are also odors which resemble four primaries, as grapefruit which falls in the center of the plane having the terminals fruity, putrid, scorched, and resinous. It is thus easily understood why it is so difficult to select a good grapefruit on the basis of odor only; one man examines them in terms of color, size, firmness, weight, and odors. It is estimated that there are at least fifty thousand different smell qualities; and, since they appear as they do on the prism, the sides become solid planes representing this large number

and their relative resemblance to each other. The prism is hollow; there is in this field, as in taste, nothing which resembles the neutral gray of vision, either when adaptation is complete or when no smell stimulus is present.



After Henning

Fig. 42.—The Smell Prism.

The behavior of olfactory sensations. We shall find that olfactory sensations vary in time and in relation to each other. If the behavior of visual sensations is taken as the criterion, the results of some combinations are not clear. Nevertheless one can be positive about several matters. What are some modes of behavior?

Adaptation. When one smells an odor, the experience immediately begins to adapt out. If one smells a given odoriferous substance constantly, the substance will become inodorous. Nothing like a neutral sensation, as the gray of

vision, remains. If and when adaptation becomes complete, no smell sensation exists. Adaptation occurs rapidly. In case of uninterrupted stimulation, adaptation becomes complete for the following substances within approximately the time indicated: heliotrope, five minutes; asafoetida, two minutes; stale cheese, eight minutes; camphor, seven minutes; balsam, four minutes; and tincture of iodine, four minutes. Adaptation is so prevalent in one's everyday experiences that it should be common knowledge. Many illustrations from everyday experiences can be cited. For instance, students in a poorly ventilated classroom, medical students in a dissecting room, workers in tanyards, and physicians and nurses in hospitals become adapted to odors with which they are surrounded. Likewise, the odor of onion soon adapts out; and one who suffers from halitosis or from body odor is usually unaware of that condition.

Smell mixtures. Here again we are forced to rely upon illustrations rather than offer a satisfactory list of complementary odors. In vision, as has been shown, the complementary colors are easily discovered; one has only to go from a given color through gray to the opposite side of the color pyramid to find the complementary color, or the color which, if mixed with it in the right proportion, will produce gray. No such method can now be followed with reference to smell qualities. It appears certain, however, that there are odors which, when mixed, do cancel each other. In the experiments the odoriferous substances themselves may be mixed or, with the use of the double olfactometer, one member of the pair may be inhaled through the one nostril and the other through the other nostril. But, however the mixture is made, certain odors cancel each other,

although complete cancellation is perhaps very infrequent. The instability of cancellation, due to difficulty in keeping the right mixture and because of the different rates of adaptation of different odors, leads some writers to suggest that cancellation is in reality only a fusion. Other writers insist that such odors as gardenia and orange blossom, carbolic acid and pulmonary gangrene, and India rubber and cedar-wood do cancel each other.

There are also odors which, if mixed in the right proportion, produce another odor. This is more like the difference tone than the intermediate color sensation produced by the mixture of noncomplementary colors. Musk and listerine, iodine and camphor, and talcum powder and perspiration are given as illustrations. The ancient effort to cancel the odor of perspiration with that of talcum powder often proves disastrous.

Many so-called odors are only fusions which may be analyzed by a trained observer. A bouquet, at first thought to give rise to one odor, may be broken up into two or more odors. Commercial perfumes, as eau de Cologne, are usually a fusion of four or five odors.

Olfactory sensitivity. It is generally thought that man's sense of smell is degenerating. As we have stated, this belief is due to the failure to discriminate between olfactory and gustatory sensations, and because man now does not have to exercise the sense of smell as a means of selfprotection. Experiments and casual observation show that olfactory sensitivity is very acute. To measure sensitivity to odors, the stimulus limen, that is, the minimum amount of odoriferous substance necessary to arouse an olfactory sensa-

tion, is determined. With the dry or liquid olfactometer, the minimum amount of surface of the smell substance may be exposed; and in other cases, a known amount of the substance may be mixed with a given amount of air. By the dilution method, it has been found that one may detect one part of musk in 8,000,000 parts of air, one part of vanillin in 10,000,000 parts of air, and one part of mercaptan in about 50,000,000,000 parts of air. The expertness of wine tasters, the small amount of incense necessary to change the odor of a room, and the olfactory effects of a particle of putrid flesh are all illustrations of the acuteness of the olfactory sense.

Some lower animals are probably much more sensitive to odors than is man. Then, too, those animals that track game usually keep their nostrils near the ground where odors are more abundant. Odoriferous particles, as gases and vapors, are generally heavier than air and lie near the ground where man does not conveniently come into contact with them. Birds, including vultures and other species which according to popular belief find their food by means of the sense of smell, probably rely for the most part on vision to discover food. Vultures have been observed to tear at an artificial carcass, and to ignore a spot reeking with odors from a concealed putrid carcass. Fish have a poor sense of smell, if any at all, and depend upon the sense of taste or its equivalent. Their ability to discriminate between different substances is very likely due to particles of the substances carried by water currents through the gill slits.

The theory of smell. The olfactory end organs, like those of vision and taste, seem to function in response to chemical reactions set up within or about them. The sense

organ consists of a membranous patch about the size of a dime, which lies in an alcove-like recess of the uppermost part of the nasal cavities. In respiration, eddy currents of air enter the alcove. If the air current is stopped in the nostril, as when a cook sniffs at food, the air currents reach the olfactory membrane more readily than when respiration is vigorous. When one suffers from a cold or a catarrhal condition, the sense organ may be covered with secretions which make the end organs inaccessible to odoriferous particles, and the patient thus becomes insensitive to smell.

The sense organ consists of slender olfactory cells and columnar supporting cells. The olfactory cells, or receptors, are slender spindle-shaped structures which have large nuclei and end in peripheral hair-like fibers. It is these peripheral processes that the odoriferous particles stimulate and in them are originated the nervous impulses which pass over the afferent nerves to the cerebrum. It is believed that the theory of specific energies or specific functions applies to the olfactory end organs. It is not known, however, how many types of end organs there are; nor has it been determined whether one cell, with its peripheral arborizations, gives rise to one or to several olfactory qualities. It is known that adaptation to one odor leaves one sensitive to other odors, and that in pathological conditions, such as partial anosmia, one is sensitive to some odors and insensitive to others. In the light of present information, based largely upon phenomena of adaptation which appear to be a means of progressive elimination of types, it would seem that there are six specific types of end organs corresponding to the six primary olfactory qualities.

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CHAPTER VII

Touch

THE field of touch, unlike that of vision, audition, taste, or smell, consists of many different sensory qualities arising from numerous types of sense organs widely distributed throughout the body. It is, therefore, not one but many sensory fields. In general, the layman has made no specific distinction between the cutaneous and the subcutaneous experiences; nor has he analyzed the field into its simple qualities. Any experience which does not belong to vision, audition, taste or smell, he calls touch, or he designates it by some common-sense name applied to the experience. He employs words like hot, hard, soft, sticky, heavy, light, and rough; and he usually associates the experiences so intimately with the physical stimulus which arouses the experience that he confuses the sensations of touch with meanings or perceptions in the field of vision or some other sense field. For example, he says the weight is heavy, the radiator is hot, the wind is cold, the water is wet, or the chair feels comfortable, without once pausing to discover the actual psychological nature of weight, heat, cold, wetness, or comfort. Now, suppose one takes a mouthful of hot coffee, or fractures a limb, or steps under a shower, or suffers nausea, or becomes dizzy. What are the sensory

processes as such, stripped of all pleasantness or unpleasantness and other associations?

Usually touch experiences are a mosaic of sensory qualities arising from sense organs which are as different from each other as the retina is different from the olfactory membrane. Pain is different from neutral pressure, cold from warmth, ache from bright pressure. Our problem includes the task of separating the simple qualities and describing each one of them as best we can. To do this, it will be necessary to explain every typical part of the body—the skin, the muscles, the joints, the tendons, the viscera, the semicircular canals—in order that no type of sensory quality may be omitted. All kinds of stimuli—mechanical, electrical, chemical, and thermal—must be used systematically so that the various end organs will be made to function. In view of the large number of different sensory qualities and blends, the millions of anatomically separate sense organs, and the simultaneous stimulation of different types of sense organs, the task becomes difficult and extensive. For the sake of clearness, we shall divide touch into two parts, namely, the cutaneous and the subcutaneous.

Cutaneous

The cutaneous area embraces the thin plastic covering of the body. It includes not only the skin proper, but also the lining of the nasal cavities, the mouth and throat, the auditory meatus, the conjunctiva, and the red area of the lips. This membranous covering of the body, altogether large in extent, is literally inlaid with sense organs. It contains an average of about 140 sense organs per square centimeter.

Both the number and the sensitivity of these sense organs vary with different areas of the skin.

The cutaneous qualities. The primary cutaneous qualities seem to be five in number, namely, warmth, cold, neutral pressure, clear pain, and tickle. Each one of these should be examined and described in its own right, irrespective of the nature of the physical stimuli which must be employed to arouse the sensation itself.

Warmth. Suppose one brings lightly over the skin the end of a slightly warm temperature cylinder or a blunted lead pencil. Here and there will be discovered a spot that is distinctly warm. This is pure warmth; it is an experience which is intrinsically warm, irrespective of any association that the observer may make with specific physical temperature or physical stimulus. The experience is light, fluffy, airy, soft, cloud-like, fog-like, and voluminous; it is irregular in texture and shape; it is never very dense; it seems to well up from beneath, coming gradually into full intensity. In an effort to find an illustration, one may describe it somewhat as if it were a very small body of warm air or fog within the skin.

On an average, there are in the skin about two warm spots per square centimeter. They seem to function best when the physical stimulus is a little above skin temperature. Physiological zero for the skin varies under different conditions, but in general it is about 33° C. If the temperature of a cylinder which one uses to arouse the experience is about 40° C., the spots may be found easily. The sense organs can be stimulated singly by the use of temperature cylinders or other instruments with which a small area of the skin is excited. They can also be stimulated in large

numbers by blood rushing to the skin, as when one feels shame; by warm air or by radiant physical heat affecting the skin; and, chemically, by pepper, acids, and mustard.

Adaptation occurs quickly when one stimulates constantly a single warm spot. Adaptation usually becomes complete within about one minute or less when this punctiform method of stimulation is employed. When, however, large areas and intense stimuli are involved, adaptation is much slower. There is also general adaptation. For example, the too-warm water of the tub may become all right, or the warm days of summer may become less unpleasant. Moreover, by means of one's general adaptation to warmth, a cool day in a summer may seem uncomfortably cold. Positive afterimages are very obvious. For instance, when the physical stimulus is removed, the sensation of warmth may continue for a second or for a longer period of time.

Cold. Casual or systematic exploration of the skin with a dull pencil, a blunt nail, or a temperature cylinder, reveals the existence of small areas or spots which, when stimulated, produce the pure sensation cold. This experience is rather dense, compact, and uniformly smooth in texture. It seems to lance downward and to come into full size and intensity quickly. Its limits are sharply outlined; that is, it is somewhat as if a small pellet of ice were resting within the skin.

The number of cold spots per square centimeter varies with different parts of the skin. The average is about 12, although the number ranges somewhat as follows: palm of hand, 2; cheek, 8; abdomen, 12; lower lip, 16. These cold spots function best when the physical stimulus is a little below skin temperature, that is, about 28° to 23° C. As in the case of warmth, no fixed temperature can be named as

physiological zero to cold, for there is adjustment through a condition similar to, if not, adaptation.

Adaptation occurs both to punctiform cold and to cold in general. The time required for complete adaptation when one cold spot is stimulated varies from 4 to 90 seconds. When large areas and intense stimuli are involved, it is doubtful whether adaptation becomes complete. There is, however, something like general adaptation, for one becomes accustomed to the cold of winter, as he does to the warmth of summer. In some way the threshold of sensitivity to cold becomes lower in winter and somewhat higher in summer, irrespective of whether or not such adjustment should be called adaptation.

Paradoxical cold is a peculiar phenomenon. As we have said, the cold spots are aroused more easily when the physical stimulus is below skin temperature, that is below 33° C.; but they do give clear sensations of cold at 45° C. and above until the physical cold becomes so intense as to produce pain. Why they do not respond for about 8 degrees above physiological zero, and then do respond to higher temperatures is a paradoxical fact that we do not understand. In view of the fact that the end organs of cold respond more quickly than do those of warmth, the fact of paradoxical cold may explain why one may feel cold for a moment when one steps under a physically warm shower.

Positive afterimages of cold are clear and persistent. If one stimulates a single cold spot, the sensation continues for a moment after the stimulus has been removed. Likewise, if a large area is stimulated intensely, the cold persists. For example, lay a cold coin on the forehead or against the lips, and it will be noticed that the sensation of cold lasts

for two or three seconds after the physical object has been removed.

Neutral pressure. Neutral pressure is the most prevalent of several types of pressure. But ordinarily it is so mixed with other cutaneous qualities that its essential characteristics are seldom noticed. For example, lay a cube of ordinary ice on the skin; neutral pressure is present with the cold. Lay a hot coin on the skin, pressure occurs along with the pain from the injured skin. In such instances one's attention usually is attracted primarily to the cold and the pain, so that the pressure is overlooked or forgotten. But let the skin be explored systematically in an effort to discover pressure as such. This can be done by means of a horse-hair attached by sealing wax to the end of a small stick, by moving a single hair on hair-covered areas of the skin with the point of a pencil, by traction from a string glued to the skin, or by placing against the skin the end of a small tube in which a vacuum is induced. The horse hair is the most convenient form of stimulus, for, however much it may be bent, it will not stimulate subcutaneous sense organs.

The sensory experience arising from the stimulation of the sense organs of neutral pressure varies in quality with the increase of intensity of the stimulus. For example, move a single hair on the back of the hand, or touch lightly the pressure spot which lies on the windward side of the hair that enters the skin obliquely; the sensation will be a light, wiry, springy, diffuse experience, somewhat like tickle. This pressure quality is called contact and is probably an intermediate, falling between tickle and neutral pressure. Now increase the intensity of the stimulus; the experience consequently becomes more dense, compact, dull, inert, drab, and

it is somewhat granular in texture. It is like a lump or granular object embedded in the skin. Its outlines are not so clear as are those of cold.

The pressure spots occur in almost every part of the skin; the conjunctiva and small parts of the oral cavity seem to be the only exceptions. The average number per square centimeter is about 25, although the number varies from a few on the lower leg to a large number on the lips, the scalp, and the finger tips. Examples of this variation are: lower leg, 6; back, 28; ball of thumb, 135. In general there are more pressure spots on the scalp, face, and extremities of the limbs than there are in other regions. Moreover, the pressure spots are much more sensitive in some regions than in others. The difference, however, is probably due rather to differences in accessibility than to inherent differences in the end organs as such. For illustration, from the point of view of the threshold or stimulus limen, the pressure end organs of the lips are eight times as sensitive as are those of the back, and those on the finger tips about twice as sensitive as those on the dorsal side of the hand.

Adaptation to neutral pressure occurs readily, whether a punctiform or a large stimulus is applied. If a small-sized object is applied lightly to the skin, the sensation of pressure will rapidly become weaker and finally vanish, provided the stimulus is kept constant. In everyday experience one becomes adapted to the pressure of one's clothing, spectacles, wrist watch, ring, and other objects which may produce constant stimulation. If pressure reappears when the stimulus is removed, it is because the readjustment of the plastic skin restimulates the end organs.

The positive afterimage of pressure may be observed with-

out difficulty. Move a single hair or a large number of them, touch the lips, nose, or finger tips, or remove a rubber band from a finger. The skin undergoes readjustment when the physical stimulus is removed and the end organ of pressure is stimulated when such changes occur. There is no negative afterimage of pressure. Whenever one seems to experience a negative afterimage in touch, the experience is caused by some vascular change in the skin, or by some other fluid or tissue modification.

Clear pain. We have already discovered the richness of cutaneous sensitivity. But let the exploration continue. Jab the skin with the sharp point of a needle, and a point of new experience—a burning, itching, stinging, prickly, lively, smarting pain—will arise. Again, with a rough cloth and soap scrub the back of the hand until the insensitive epidermis has been removed, and then touch the exposed tender dermis with a needle or bristle; or, when your razor has by chance cut away the epidermis, apply sodium chloride or alcohol to the raw area. Other chemicals, as formic acid, and electrical stimuli, burn quickly or irritate severely and easily arouse sensations of clear pain.

The end organs of clear pain are probably the free nerve endings in the dermis or live part of the skin. These nerve endings are found in areas insensitive to other touch experiences. The skin may be treated with drugs which affect only these nerve endings, leaving warmth, cold, and neutral pressure unaffected. The pain spots are very numerous, there being an average of about 100 per square centimeter. The distribution varies from none at places on the inside of the cheeks to more than 200 per square centimeter on the neck. It is, however, almost impossible to find any part of

the skin, except small areas in the oral cavity, which, if stimulated sharply by any of the usual methods, will not arouse sensations of pain. Sensitivity to clear pain seems to vary with different parts of the body. The difference is not caused by a difference in responsiveness of receptors, but is due to the greater thickness of the epidermis and the smaller number of nerve endings in the less sensitive areas. For example, the ball of the thumb is not very sensitive to pain, while the eyelids, the anterior parts of the neck, and the tympanic membrane are highly sensitive. The tympanic membrane, like the exposed nerve of a tooth or a fresh open wound, is so sensitive as to give rise to pain so dense, so compact and lancing, and so unbearable that it is often considered different in quality from clear pain and is, therefore, sometimes perhaps more accurately, classified as quick pain.

Adaptation to clear pain is very rare. It will occur, however, when the stimulus is not too intense and is applied with constant intensity to the same area. It is unlikely that the observer could endure the so-called quick pain long enough for adaptation to occur.

Positive afterimages almost always occur after the physical stimulus has been removed. With the use of chemicals it is difficult to discover when the irritant is no longer present. One can know, however, the instant a mechanical or electrical stimulus leaves the skin. The pain from the prick of a needle may persist for a minute or longer, while more intense physical stimuli may produce pain which will last several minutes.

Tickle. If one moves a hair or string lightly over the lips, he will experience a light, springy, dancing, ticklish experience. This type of experience may also be had by

brushing the nasal cavities, the auditory meatus, and the soles of the feet lightly with a thread or feather. It is not the same as the complex sensory experience that one has when one is severely stimulated below the armpits, for the sensation of tickle is more like light, alive, springy granules of sensory substance. Tickle may be pleasant or unpleasant, depending largely upon the attitude of the observer. As a rule, the experience becomes unpleasant when the stimulus is applied to the red areas of the lips, the nasal cavities, or the auditory meatus. Tickle must be regarded, however, as sensation, and not as affection, for the affective quality is not intrinsic to tickle.

Positive afterimages occur with tickle, but adaptation does not. The physical stimulus of tickle is a moving object, which explains the absence of the phenomenon of adaptation.

There are numerous intermediate cutaneous qualities, such as contact which lies between tickle and neutral pressure, and itch which lies between tickle and clear pain. But experimental work at this time seems to give no satisfactory list or classification of intermediates. It is likely, however, that the number of the intermediates is small.

Touch blends or fusions. What occurs when cutaneous end organs of different types are stimulated simultaneously? In some instances the components may be analyzed out, just as one can detect the fundamental and the overtones when a piano string is plucked, or one can distinguish the sour and the sweet of sweetened lemonade. Clear pain and neutral pressure fall apart under introspection. Other combinations produce a phenomenon which resembles the second law of color mixture. Suppose, for instance, one arouses

punctiform cold and warmth by the simultaneous stimulation of one cold spot and one warm spot located near each other. The resulting experience is not cold and warmth, but a blend which in quality is a burning, itching, stinging experience called heat. Likewise, if by means of a tempera-

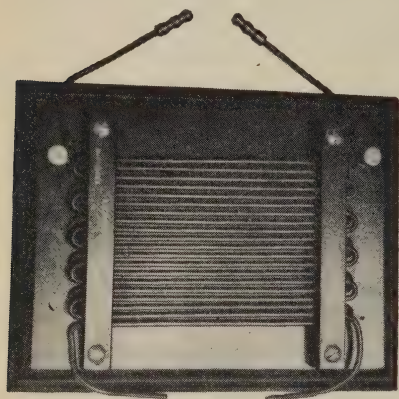


Fig. 43.—Dallenbach's Temperature Grill.

ture grill, large numbers of cold spots and warm spots are stimulated simultaneously, the experience of heat will be so pronounced that the observer, who is blindfolded and who is unaware of the nature of the physical stimulus, may believe the skin has been blistered. The cold water and warm

water, run through alternate tubes of the grill, need not be below 25° C. or above 40° C.

Wetness may be produced by simultaneous stimulation of cold spots and pressure spots. No liquid is necessary to give psychological wetness. If a cool, dry silver half dollar is placed on the forehead which is sensitive to cold and pressure, cold water may seem to trickle over that section of the skin. Wet clothing closely draped about the body seems very wet if a cool wind blows. But, strangely enough, when one's limbs are submerged in warm water they do not feel wet. Warmth and neutral pressure give a smooth, oily, greasy experience generally characterized as oiliness. This is the sort of experience one has when one's clothes are

saturated with perspiration on a hot summer's day, or when a jet of warm air is blown lightly across the dry skin. Clamminess is a blend of cold and pressure had under peculiar conditions.

The theory of cutaneous sense organs. We have said that the skin is a large pliable covering of the body, inlaid with an average of about 2 warm spots, 12 cold spots, 25 pressure spots, and 100 pain spots per square centimeter. Tickle and ache must not be omitted, although it may be that no separate system of receptors exists for them. What are the cutaneous receptors, and how do they function? It appears that the doctrine of specific functions applies to cutaneous end organs; yet histological investigations have left much doubt concerning some of the sense organs. The majority of writers seem to state that Ruffini's cylinder is the end organ of warmth. This structure is a cylindrical corpuscle containing a bundle of hair-like nerve endings. It lies rather deep down on the cutis. Krause's bulbs are often listed as the sense organ of cold. This structure is somewhat bud shaped and contains a group of very small peripheral nerve endings. Within recent years, histological examination of sections of the skin which constantly produced sensations of warmth and cold have shown no trace of a Ruffini's cylinder or a Krause's bulb. Numerous undifferentiated nerve endings have been revealed, and it appears that, for the time being, these must be regarded as the receptors of warmth and cold, although we do not understand how different sensory qualities may arise from them.

The receptors for neutral pressure are the hair follicles in those parts of the skin covered with hair, and Meissner's corpuscles in the hairless areas such as the tongue and finger

tips. The end organ at the hair follicle consists of a ring of peripheral nerve endings surrounding the hair follicle. The end organ may be stimulated by pressing lightly on the windward side of a hair, or by moving the hair itself. When the hair is moved, it acts as a lever resting against the inelastic epidermis which serves as a fulcrum; and, since the nerve endings lie around the root of the hair, they are readily disturbed. The Meissner's corpuscle is an irregular, elongated bundle of nerve endings. There are perhaps more than 500,000 pressure spots, including the hair follicles and Meissner's corpuscles, in the skin.

The end organ of clear pain is not a specialized group or bundle of nerve endings; it consists of the free nerve endings within the dermis. These receptors are, by far, more numerous than any others in the skin. As we have seen, they may be stimulated mechanically, thermally, or electrically, in small or in large areas. It is estimated that there are about 2 million of them in the skin.

The receptors of tickle are unknown. On account of the apparent relation of tickle to neutral pressure, it is believed that the same end organ, stimulated differently, may give rise to different qualitative experiences. Ache probably arises from direct stimulation of nerve ganglia or nerve trunks. Severe physical pressure, as from grasping the skin with the finger and the thumb, or a pathological condition, as a cutaneous ulcer, is sufficient to set up the nervous impulse.

A description of just what takes place within or about the cutaneous sense organs to set up the nervous impulse is theoretical. In vision, taste, and smell, chemical reactions seem to occur in the sense organs; the sense organ of audition is mechanical. It is believed that the cutaneous receptors

are, for the most part at least, aroused mechanically. The mechanical stimulation may be direct, as by depressing, stretching, or pulling the skin outward. When the hand is placed in a bucket of water, a ring of pressure is experienced at the surface where the skin is slightly bent. Warm spots, cold spots, and pain spots may likewise be aroused by direct stimulation with a physical object. Indirectly, the end organs may be stimulated by weak electrical impulses, chemicals, and emotions. Alcohol arouses the sensation cold, carbon dioxide provokes warmth, and a feeling of shame may make the face feel hot. Such stimuli also provoke vascular and muscular changes which in turn stimulate the nerve endings. Both the direct and indirect modes of stimulation seem to modify the osmotic pressure of the area of the skin involved. Of course, as we have seen, pain and ache can be aroused by injury to the receptors or to the nerve trunks.

Subcutaneous

This section of touch, frequently designated as kinaesthesia, here includes the sensory qualities that arise from such cutaneous areas as the muscles, the joints, the periosteum, the tendons, the viscera, and the semicircular canals. The scope and the inaccessibility of the field are obvious. Moreover, the sensations are usually mixed with each other and with associated sensations and images from other sense fields. For example, move the head, lift a book, walk, yawn, extend the arm, grasp a pen, throw a ball, suffer nausea—all such general experiences normally involve various muscles, joints, and tendons, and cutaneous and visual experiences as well. Subcutaneous qualities are, in several instances, similar to

cutaneous qualities. Furthermore, deep-seated sensations are frequently referred by the subject to areas near the surface of the body, a fact that any competent physician knows. Our problem, then, consists of separating subcutaneous sensations from each other and from cutaneous experiences. This analysis demands both the elimination of cutaneous sensitivity and the use of rigid introspection.

For our examination of muscles, tendons, and joints, let us use the arm and the hand. The skin can be made anaesthetic by an intracutaneous injection of cocaine, or by spraying it with ether for several minutes. The latter method is generally used in the psychological laboratory. Subcutaneous parts may then be stimulated in various ways. From the muscles, tendons, and joints, five, perhaps six, different qualities appear.

The qualities of subcutaneous experience. If one presses down on a muscle lightly, dull pressure, a sensation resembling neutral pressure, can be observed. It is described as a dull, dead, drab, inert, diffuse, inactive pressure experience. If the intensity of the physical stimulus is increased, the experience becomes dull pain. This sensation is a dull, diffuse, painful experience similar to a dull headache. If one exhausts the muscles of the arm by constant stimulation with an ergograph, dull pain may be observed easily in the hand and arm. If the muscle is struck sharply with a blunt object or is grasped severely between the thumb and fingers, a dense, compact experience called ache is produced. This sensory quality may be had from sore muscles, abscesses, fractured bones, and numerous other sources. Its extent and intensity, of course, vary widely according to the

scope and degree of injury. Another quality, called bright pressure, is said to be intimately associated with the muscles, although it is probably not restricted to them. This sensory experience is characterized as light, airy, fluffy, dancing, shimmering, flashing, active, thrilling. It is the type of experience one feels in one's legs and chest on the occasion of a frosty morning when one feels particularly energetic and well.

From the tendons appears a vague sensory quality known as strain. Push with the hand against the desk, stand on one foot for ten minutes, hold a weight at arm's length from the body for a few minutes, or raise the ergograph weight with the forefinger. The sensation of strain will appear along with other sensory qualities, but it is sufficiently unlike them to be isolated and observed. As the intensity of the stimulus increases, or as fatigue becomes more pronounced, strain gives place first to dull pain and finally to ache.

The joints give a peculiar pressure quality, known as smooth pressure to differentiate it from other pressures. Smooth pressure rarely attracts one's attention, because as a rule it is so weak in intensity as to be overshadowed by other tactual sensations. If, however, the skin at the wrist is anaesthetized or if the joint is stimulated abnormally, the pressure will be clear. For instance, grasp the arm near the wrist with the right hand; then move the left hand slowly to and fro; in the wrist joint may be noticed an oily, greasy, smooth pressure. If the first joint only of the index finger is flexed or if the ankle joint is moved, smooth pressure is easily observed. This quality in all probability is produced by the stimulation of any joint, although, as has

been pointed out, it is usually not sufficiently intense to attract attention, or it is so mixed with other touch qualities as to be unrecognized.

The behavior of subcutaneous qualities. Positive after-images occur in the case of all the subcutaneous sensory experiences that we have mentioned. Here again the sensation does not terminate at the moment the stimulus is removed. The duration of the positive afterimage varies with different sense qualities as well as with different degrees of intensity of stimulation. Dull pressure may last a second; intense ache may persist for several minutes. Negative afterimages and contrast probably never occur in subcutaneous experience.

There appears to be general agreement about the sense organs of the muscles, tendons, and joints, although the statements offered are not above question. In the muscles are found free nerve endings, Pacinian corpuscles, and muscle spindles, which are adequate for dull pressure, ache, and bright pressure. It is thought that the free nerve endings produce pain and ache, the muscle spindles dull pressure, and the Pacinian corpuscles bright pressure; but adequate information has not yet been found. The Pacinian corpuscles are found in the tendons and are believed to be the end organs of strain. Free nerve endings and Pacinian corpuscles are also found in the fascia, ligaments, synovial membrane, and periosteum. Free nerve endings occur in bone tissue and make it highly sensitive to pain. No one who has suffered from rheumatism, a dislocated joint, or from broken bones doubts that the areas in question are abundantly supplied with receptors.

The visceral sensations. The available information about visceral sensitivity is as uncertain in completeness as it is extensive. Physiology, surgery, and psychology furnish sufficient data to show the general nature of the sensory qualities, despite the inaccessibility of a large part of the structures involved. Surgery reports that the viscera are almost, if not entirely, insensitive. It appears that the heart, the lungs, the stomach, the intestines, the liver, the gall bladder, the kidneys, and other structures may be torn, cut, and burned without producing pain or other sensations. On the other hand, the peritoneum, the pericardium, the pleura, and other membranes are very sensitive to pain and in some measure to pressure. Gas pains, pleurisy, pericarditis, and other pathological conditions are positive evidence of the sensitivity of the structures. Physiology is not, however, in complete agreement with surgery, for it shows an abundance of sensory nerves in the viscera. It also calls attention to the matter of adequate stimuli, and the abnormal conditions attending an operation.

Referred experience appears here. For example, cardiac pains may be located in the shoulder, and gall bladder pains may be felt in the neck. An inflamed and tender appendix may produce deep-seated pain near the vermiform appendix itself or in the diaphragm below the sternum. Psychology has very limited access to the internal organs, but it does inquire about pains produced by such pathological conditions as angina pectoris, gastric ulcers, and kidney stones. It moreover asks about hunger and thirst, and about pain in the esophagus and stomach when certain irritants are swallowed.

The esophagus, the stomach, and other parts of the alimentary canal have been explored by means of thermal, mechanical, electrical, and other stimuli. The sensations are not so clear cut as those produced by cutaneous receptors; nevertheless, the observers report warmth, cold, dull pain, pressure, and ache. Such experiences appear to be normal, and seem to be a necessary means of controlling the individual's habits of eating and drinking. For instance, the normal individual will cease to eat when his hunger is allayed; but in cases of visceral anaesthesia the patient's food must be measured, because he cannot tell when he has eaten enough. Moreover, in case of gastric ulcers the patient is warned by pain against rough foods or other irritants.

Complex organic experiences of interesting patterns or mosaics of sensory experience occur. What, for example, are the components of such complexes as hunger, thirst, and nausea? Hunger starts with dull pressure localized in the region of the stomach, and is temporally coincident with peristaltic contractions of the muscular walls of the stomach. Proof of the relation of the sensory experience and the peristaltic contractions has been obtained by means of experiment. For instance, an observer swallows a rubber tube, to one end of which is attached an inflated balloon and to the other end a writing stylus resting against a revolving drum covered with smoked paper, so that a record of the contractions may be had. As the intensity increases, the experience becomes a gnawing, aching pain. If no food is taken for several days, the sensations cease. One need feel no sympathy for a hunger striker, for he does not suffer the pangs of hunger after the first few days.

Thirst is primarily pressure. The experience of pressure is localized in the soft palate and other membranes of the

mouth and upper parts of the throat. The tissues become dry, and so set up pressure sensations more easily. Thirst may be provoked by eating crackers or other dry substances which quickly absorb the moisture in the mouth. It may

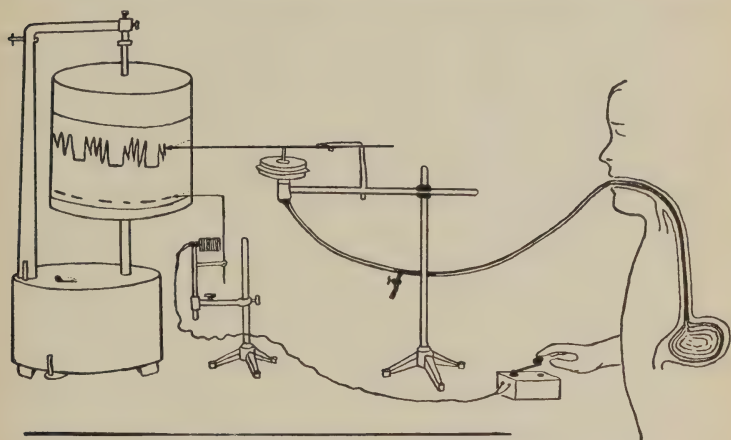


Fig. 44.—Method of Recording Contractions of the Stomach.

be quenched momentarily by moistening the mouth with water or lemon juice, or by the use of drugs which induce secretions in the membranes of the mouth and throat.

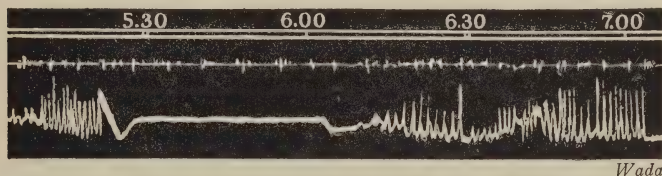


Fig. 45.—A Kymograph Record Showing Stomach Contractions During Hunger.

Nausea is usually much more complex than hunger or thirst. It may develop in various ways, depending upon the type of stimuli employed. Observers who swallowed a small amount of tobacco juice reported at first a lump of

dull pressure in the stomach. The experience then spread until it included sensations from violent contractions of the muscles of the abdominal wall and the diaphragm, dizziness, cold sweat, odors, and a bitter taste. At times vision is disturbed, and general muscular tremors may appear.

The inner ear. In another chapter it was said that the inner ear consists of the cochlea, a snail-shaped structure which contains the membranous labyrinth in which is located the end organ of audition, and the semicircular canals and the vestibuli which have no direct relation to sensations of hearing. These latter structures do furnish nervous impulses and sensations which aid in muscular coördination and give a sensory basis for the perceptions of position and direction of movement. Here again the inaccessibility of the structures in the human skull and our inability to stimulate them normally without involving many other sensory areas make uncertain one's knowledge of how they function and just what pure sensations they produce. Their general structure is, however, well known.

There are three semicircular canals in each ear. Externally, they are bony, semicircular structures set in the three dimensions of space, and joined at the base by an enlargement called the utricle. Near the basal end of each canal is a swelling, the ampulla. Within these bony canals, separated from them by perilymph, are the membranous semicircular canals. The membranous canals and the utricle are approximately filled with endolymph. In the ampulla lies the *crista acustica*, a high, rounded structure projecting from the outer inside wall into the endolymph. The *crista* contains cylindrical hair cells, each of which terminates peripherally in a hair or a bundle of hair-like processes which

project into the canal. To the wall of the utriculus is attached the utricular macula. The macula consists essentially of a mass of hair-like nerve endings surrounded by masses of small calcium carbonate particles, the otoliths. The saccule, which lies near the utriculus, also contains a macula attached to one of its walls.

The *cristae acusticae* and the maculae are probably stimulated hydromechanically. When a tube, partially filled with water, is moved forward the liquid will lag behind. If the tube moves forward at a uniform rate, the liquid will finally adjust itself to the movement of the tube; if the tube is stopped suddenly, the liquid will rush forward. In all probability such hydraulic changes occur in the semicircular canals, in the utriculi, and in the sacculi. As previously stated, the three canals are set in the three dimensional planes. Suppose, then, one moves forward or backward, to the right or to the left, or perpendicularly as when one rides in an elevator; in each case one canal in each ear is affected. When the head is rotated, or when one spins on one's heel or is whirled about in a chair, the canals of more than one plane may be affected. Whenever the liquid lags behind or rushes forward, the hair-like nerve endings are bent. In the case of the macula, the otoliths press against and bend back and forth the hair processes of that structure.

The sensation produced by the semicircular canals, and apparently also by the maculae, is a light diffuse pressure. There are many other associated responses, some of which are psychological while others are merely reflex organic reactions. When the semicircular canals are stimulated directly, as by violent movements or electricity, dizziness occurs. They also appear to be affected by certain drugs, by

alcohol, by abnormal pressure on the tympanic membrane, by looking down from the observation tower of a skyscraper, and by watching moving objects that cause nystagmus. Deaf-mutes, whose semicircular canals do not function, and animals, whose canals have been destroyed, do not normally experience dizziness. Moreover, such deaf persons, when blindfolded, have a deficient perception of the direction of movement and of the position of the body. For example, they would be in danger of being thrown by centrifugal force from the hobbyhorses of a merry-go-round; and, despite other experiences, they might swim toward the bottom if permitted to dive into deep water. It must not, however, be thought that equilibrium, vertigo, and the like are entirely dependent, as perceptive experiences, upon the functions of the inner ear. Even casual observation is sufficient to show that the eyes, muscles of the feet and legs, and the viscera are usually involved. But we shall discuss perception in another place.

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CHAPTER VIII

Intensity of Sensation

IN THE preceding sections the human organism has been explored in an effort to discover the typical psychological experiences produced by the stimulation of different sense fields. Four of the sense fields, we found, are each confined to a small area and perform in general one type of function; the fifth, touch, is widely distributed throughout the body and in reality embraces several different types of sense organs which perform different rôles. Altogether there are several million touch receptors, to say nothing of the vast number of specialized nerve endings in such structures as the retina and the inner ear. Heretofore, we have been concerned primarily with one attribute of sensation, that is, quality; and, from this point of view, such qualities as colors, tones, sours, pains, and musk have been listed. It was noted that those qualities were limited both with respect to modes of arousal and to degrees of saturation or intensity. Since we have examined sensation primarily from the point of view of quality, we shall, therefore, now examine another attribute, namely, intensity, in our effort to understand further the essential nature of sensation.

As was stated in an earlier section, the attribute of intensity is indispensable to sensation. Every sensation possesses intensity to some degree. A tone may be very weak

or very loud; a red may be just perceptibly red or a deeply saturated red; a brightness may vary from that of the faintest visible star to the brilliance of the sun; a taste may be just noticeably sweet or as intensely sweet as syrup. Likewise, every type of sensory quality has its range of differences in intensity.

Now, in order that intensity may be understood, a somewhat systematic plan of study must be followed. We shall, therefore, discuss intensity under three general heads—first, the stimulus limen; second, the terminal limen; and, third, the barely noticeable differences, or difference limen.

The stimulus limen. The stimulus limen, the *RL*, is defined as the weakest stimulus which, in a given field, may produce sensation. For instance, if a few grains of sugar are added to a glass of water, the water will not taste sweet; but if, say, one fourth of a teaspoonful is added, sweet can just be noticed. A tuning fork which vibrates very weakly cannot be heard; but if the intensity of the vibrations is gradually increased, a faint tone will finally be noticed. A tiny stream of sand falling a distance of one foot upon a table makes no sound, but if the stream is gradually enlarged a barely perceptible hiss or noise will be heard. A small flake of cigarette ash or a piece of down, falling on the skin, produces no sensation; a physically heavier mass would be noticeable. All about us, then, associated with every sense field, are physical stimuli. Some of them are too weak to produce a sensation, others call forth barely perceptible sensations, and still others are well above the stimulus limen.

Those stimuli, as an unseen star, the ticking of my watch on the desk, the grain of salt dissolved in a glass of water, are called subliminal. Physically they exist, but they are

not strong enough to produce a state of consciousness. Many of them probably do not disturb the sense organ in question. For convenience and to be somewhat specific, it is agreed that physical stimuli which, in a long series of observations in a given field, evoke no sensation, or arouse sensation less than 50 per cent of the time, will be called subliminal; while those that produce sensation 50 per cent of the time will be regarded as liminal, or the threshold stimulus to sensitivity.

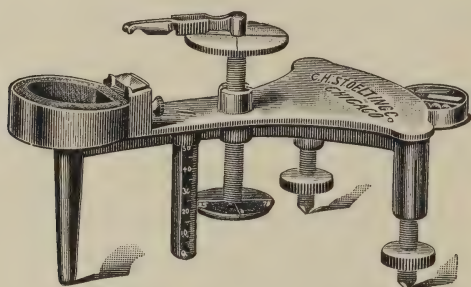
The stimulus limen varies with different individuals; it also varies with the same individual under different conditions. It must be determined experimentally by the use of known stimuli applied under known conditions. The average stimulus, as determined by a large number of observations made under controlled conditions by normal observers, can here be regarded as the minimum stimulus to sensitivity. However, it must be remembered that general fatigue, adaptation, and environmental conditions frequently influence the observer and cause variations in sensitivity. For example, a pinhole of light which cannot be seen normally is easily seen when one has become dark-adapted; dark-adaptation increases sensitivity 10,000 times, while light-adaptation decreases it correspondingly. Moreover, a candle or a star, whose light is invisible in daylight, may be seen easily at night when the physical environment is different. It must also be remembered that different sense fields differ in liminal sensitivity, and, as in the case of touch, the same types of sense organs respond more easily in one part of the body than in others. With the fact of such variations in mind, let us turn to illustrations of stimulus limens in different sense fields.

The energy required to produce liminal sensations is, especially in some sense fields, exceedingly small. For the normal unadapted eye, the threshold for brightness is about 2,750 microwatts per square meter of illuminated surface when the stimuli fall upon the center of the retina. A microwatt is $\frac{1}{1,000,000}$ of a watt. For the dark-adapted eye, the threshold is approximately 0.275 microwatts. If the stimulus falls on the periphery, the sensitivity threshold is very much lower, probably because the rods are more sensitive to brightness than are the cones. Suppose we take a familiar object of vision, say, a very faint star seen by peripheral vision. In this case the image is both exceedingly small and very weak. The amount of energy received by the retina from the star is estimated as about $\frac{1}{100,000,000,000,000}$ of a watt. Compare the energy of this stimulus with that of an ordinary 60-watt light! The sensitivity of the retina is amazingly high.

Audition offers another sense field in which the energy exerted by physical stimuli can be measured with reasonable accuracy by the use of acoumeters and audiometers. With the acoumeter one may compute the energy involved when a steel ball falls a known distance and strikes an ebony or a glass plate. Tuning forks, which produce pure tones, are measured in terms of power or microwatts, the vibration rate and amplitude being known. The threshold is least between 2,000 v.p.s. and 4,000 v.p.s., where it is approximately $\frac{4}{10,000,000,000}$ of a microwatt. The limen increases for lower and higher pitches. In general, vision and audition have about the same threshold values, as judged in terms of the energy required for the arousal of minimal sensations.

Accurate measurement of the actual amount of energy re-

quired for the stimulation of the end organ of smell is apparently impossible. The energy of odoriferous particles cannot be measured, nor can the particles be applied to the sense organ in the same way as light waves and sound waves are controlled. By the use of olfactometers, air currents are drawn over a known amount of surface of smell substance,



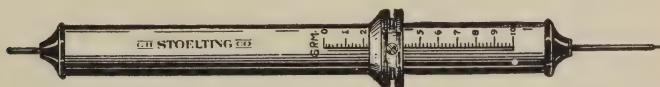
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Fig. 46.—Lehmann's Acoumeter. (This instrument is used to determine the stimulus limen and difference limens for sound.)

and relative measurements are thus obtained. Or a known amount of liquid or soluble smell substance, as musk, is diluted with known amounts of air, until the threshold limen has been discovered. For illustration, to find the threshold for musk, dilution of the musk with air continues until the minimum amount that can be detected in, say, a liter of air is found. As we have already seen, smell is a very acute sense. In dilution, 1 part of vanillin may be detected in 10,000,000 parts of air. The threshold for mercaptan is given by one writer as $\frac{1}{460,000,000,000}$ of a gram in 1 cm^3 of air, and by another as $\frac{43}{100,000,000,000}$ of a gram in 1 cm^3 of air. It is furthermore stated that in one breath of air, only a small part of which reaches the olfactory membrane, a mere $\frac{22}{10,000,000,000,000}$

of a gram of mercaptan can be detected. Such a high degree of sensitivity is almost inconceivable.

When compared with vision, audition, and smell, taste is as obtuse in sensitivity as it is poverty stricken in qualities. The threshold limen for sweet, when a sugar solution is used, is $\frac{5}{1,000}$ of a gram per cm^3 of water; for bitter, when quinine is used, $\frac{5}{10,000,000}$ of a gram per cm^3 of water; while salt and sour are much less effective. Here, too, as in the case of smell, only a small amount of the taste substance actually reaches the receptors within the taste bud.



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Fig. 47.—Head's Algesimeter. (This instrument is used to determine the stimulus limen for clear pain.)

Measurements of liminal stimuli in touch are, in general, not satisfactory. The sensitivity varies with different sections of the body, and in some cases, as in clear pain, the depth of the end organ in the tissue may cause a difference in the amount of energy required to arouse the sensation. Pressure, as examined experimentally by von Frey, shows a threshold value of about 0.83 gm. per sq. mm. Pain is less sensitive; the amount of pressure required to produce pain is partly dependent upon the structure of the epidermis which is much thicker at some places than at others. It will be recalled that pain is also aroused by physical temperatures. A physical stimulus of about 10° C. or 50° C. will produce the sensation of pain. On account of the inaccessibility of the end organs, no satisfactory data concerning the threshold of subcutaneous sensitivity are now available.

The terminal limen. There are in every sense field the maximum sensory intensities which one can safely experience. For example, there is the most intense brightness, the loudest noise, the most severe quick pain, and the most intense sweet which one can experience. As the threshold stimulus is the weakest audible tone of a given area of the tonal scale, the terminal stimulus, *TL*, is the loudest tone of that section. The maximum intensities, whenever determined, must be discovered experimentally. In several relations intense stimuli are injurious to the sense organs involved, and therefore the upper limit of sensitivity must be assumed or fixed arbitrarily. For instance, bright lights may cause irreparable damage to the retina, and loud sounds or explosions not infrequently rupture the tympanic membrane or injure other structures of the auditory sense organ. It must also be noted in this relation that the limen for each sense field must be determined for that field. Moreover, a single sense field may embrace several qualitative orders and so may require a statement of several limens. Vision thus includes colors and brightness; the maximum saturation of blue does not conform to the maximum for brightness, for the two are not of the same qualitative order.

The upper limit of brightness, as determined by white paper in direct sunlight, is about 16,500,000,000 microwatts, while the brightness of the disk of the sun is so much greater that direct observation is dangerous. With tones of 2,048 v.p.s., the terminal limen is approximately 5,000 microwatts, but the value is much higher for other pitch numbers and for some noises. The terminal limens for colors, as those for red, green and blue, must be regarded as the color of deepest saturation, that is, the reddest red, greenest green,

and bluest blue which the normal individual can observe. Limens for taste and smell cannot now be evaluated in terms of energy, for, unlike vision, audition, and some divisions of touch where the energy may be known and applied directly, the actual relation between the physical stimuli and the activity of the sense organs is unknown.

The difference limen. As we have seen, in a given sense order physical stimuli of subliminal intensity, of threshold intensity, or of maximal intensity may be applied to the sensory receptors. In vision, for instance, under carefully controlled conditions the retina has been stimulated by light so low in energy that no visual sensation was aroused; the intensity was gradually increased until the threshold stimulus was reached, and then increased until the maximum stimuli were employed. In whatever sense field they occur, and irrespective of any changes which they may effect in the end organs, subliminal stimuli produce no psychological experience. For example, if one listens to the tone produced by a tuning fork, as the vibrations become weaker the sensation becomes fainter and finally vanishes; then one simply hears no tone.

On the other hand, suppose the intensity of the vibrations is increased by small steps of equal value physically until one has passed from the *RL* to the *TL*, that is, from the minimum intensity one can hear to the maximum auditory intensity of that type of tone. What is the relation of the increments of physical intensity to just perceptible increases in sensory intensity? Does every increment of physical intensity have a commensurate psychological value? Again, suppose, by use of an acoumeter, a steel ball is dropped on an ebony plate from a height of 1 cm, and then from a height of

10 cm; if the physical intensity is thus increased 10 times, will the second thud be 10 times louder than the first? Still again, if by experiment it is discovered that when the ball falls 2 cm and then 3 cm a just noticeable increase in sensory intensity is perceived, will a difference in intensity be perceptible when the ball falls 9 cm and then 10 cm? Or, in vision, if one can detect a difference in illumination when the candle power of light is stepped up from 4 c.p. to 5 c.p., can one notice a difference when an increase is made from 30 c.p. to 31 c.p.? In short, what is the relation of physical intensity to psychological intensity?

Casual observation reveals that in the majority of sense departments there are numerous noticeable differences in intensity between the threshold limen and the terminal limen. For example, between a faint noise and the thud of a gavel on a desk there are perhaps a hundred differences in the intensity or loudness which can be distinguished the one from the others. Likewise, between a faint bitter and a very bitter taste, between a just perceptible and a saturated red, or between the weakest and the loudest tone there are many noticeable differences in sensitivity.

It is furthermore obvious that distinguishable differences must be of the same qualitative order. That is, c' is qualitatively of that pitch, whether the tone is of threshold, intermediate, or maximum intensity. Likewise, an experience of bitter is of that quality irrespective of intensity. It is obvious, therefore, that, for instance, the color red cannot form an intensive series with the odor fruity. Moreover, since within a given order the quality is a constant, the differences in sensitivity may be said to lie in a straight line which has

as its extremes the stimulus limen and the terminal limen, respectively.

It must also be noted that each one of the experiences, just distinguishable in intensity from others, must be regarded as a single psychological experience. It is no more composed of two other experiences than orange is a combination of red and yellow. Just as orange cannot be analyzed into red and yellow or pink into red and white, an intermediate intensity cannot be formed by combining a weak and an intense sensation. Likewise, 20 auditory sensations of weak intensity do not produce one of high intensity. A loud tone may be produced by physical combinations and, perhaps, at times by summation of nervous impulses, but psychologically it can no more be heard as composed of several weak tones than a light of 50 c.p. is seen as 50 lights of 1 c.p. each. Likewise, several weak sensations of sweet do not make intense sweet; many weak odors of a given quality do not produce a strong odor; a score of weak experiences of strain do not give an intense strain; nor do numerous weak sensations of noise, as the beats of a metronome, produce a loud thud like the sound from a gavel striking a desk. Each distinguishable intensity, as each primary or intermediate quality, stands, as it were, in its own right, that is, as simple.

The psychological examination of sensory discrimination, begun by E. H. Weber during the first half of the nineteenth century, not only gives information about threshold and terminal limens but also a vast number of facts about difference limens or just noticeable differences and their relation to physical stimuli. Weber and, later, Fechner, and many others made careful studies of touch, vision, and audi-

tion in an effort to discover the relation of increments of physical stimuli necessary to the discrimination of just noticeable increases in the intensity of sensation. What generally is the nature of that experimental work?

In preceding paragraphs we have noted certain facts. We have seen that the stimulus limen and the terminal limen are determined experimentally. The intensities of sensation in a given qualitative order lie in a straight line between the threshold limen and the terminal limen. The number of just noticeable differences in the series in question must be determined by psychological experiment, and not by mathematical computation. In physics the centimeter and the gram are units devised and employed to measure space and mass respectively. They are constant and may be applied generally. But the unit of psychological measurement cannot thus be fixed arbitrarily, and the unit discovered in one sense field does not obtain in another sense field, that is, the difference limen for pressure does not also hold for color. The limen in each sense order must be found through systematic observation within that order.

How are the different sense values discovered? Let us cite a simple illustration. Suppose, for example, one wished to discover the number of distinguishable differences in intensity in the series between the threshold and the terminal limens of bitter. In two glasses of water one would dissolve enough quinine to produce the taste of bitter 50 per cent of the time; this is the threshold limen. He would then use the first glass as a standard, and then dissolve in the second glass small known increments of quinine until in 50 per cent of the trials the observer could detect a difference in sensitivity between the two. Then, using the more intense mem-

ber of the pair as the standard, he would add to another glass of the same intensity small amounts of quinine until one half the time a just noticeable increase in intensity is observed. This intensity would then be used as the standard to determine the next higher intensity, and so on until the most intense bitter, that is, terminal limen is reached. The experimenter would then know both the number of just distinguishable differences of intensity in the series and the size of each one of the increments of quinine required to produce the noticeable increase in intensity.

This type of experimental procedure is used in other sense fields. In touch, for example, a weight of 16 oz. is lifted; then other weights of slightly larger magnitude are compared with it until one which is just noticeably heavier is found. The heavier is then used as the standard, and so on. In vision the threshold stimulus to brightness is discovered and used as the standard, by comparison with slightly stronger stimuli, to find the increment necessary to produce a sense difference; then the experiment is continued until the series has been completed.

It must be remembered that, in a given series, the just noticeable differences, or the difference limens, are psychologically of equal value. They are equal because, irrespective of any difference in the magnitude of the physical increments required, each one of the sense differences is a just noticeable difference. It can therefore be used in psychophysics as a unit of measurement of intensity, just as the gram and the centimeter are used as units of measurements of physical mass and space.

The results must be considered in view not only of the stimuli used but also in the light of the sense field examined.

With tones, the stimulus limens vary with different pitch numbers. A tone having the pitch number 2,048 v.p.s. gives about 366 discriminable intensities; with low tones, the number is much smaller. In vision, there are approximately 572 distinguishable brightnesses between the stimulus limen and the terminal limen; with colors, the number is smaller. In taste, the number is comparatively small. In touch, the number of difference limens varies with different sensory qualities, different cutaneous areas, various conformations of skin tissues, and diverse types of subcutaneous areas. Despite any scarcity of data, it is obvious that in the realm of sensory experience there are tens of thousands of distinguishable differences in sensitivity. The full number will not be known until the threshold and terminal limits and their intermediates are discovered in every sense field.

Weber's law. We have seen that, in a given series, the sense differences are equal in value. We have also noted that the magnitude of the physical stimulus must be increased in order to produce the sense difference. What, then, is the relation between the equal sense differences and the difference in magnitude of the physical stimuli? One will remember that in the lower pitch numbers he could see a difference in tonal quality when the difference in vibration rate was small, but with high pitch numbers the difference was much larger. He will also recall that if one lighted candle is in a room and another candle is lighted, the increase in illumination can be detected. Now, what is Weber's law, and how does it operate with reference to such barely noticeable differences?

Let us again resort to a simple experiment. Suppose one has 6 small boxes, alike in appearance, and weighing re-

spectively 16, 32, 48, 64, 80 and 96 oz. Then, taking each one of these in turn as a standard, let the observer, with the use of slightly heavier comparison weights, determine the difference limens or the physical increment necessary to produce a just perceptible increase in weight. It will be found that, when the weights are grasped, say, with the thumb and fingers, and lifted, the observer can detect a difference between a box weighing 16 oz. and another of $16\frac{1}{2}$ oz. If the fraction is smaller, no difference is discerned. It will also be found that with a 32-oz. weight, a 1-oz. increment is required; with a 48-oz. weight, $1\frac{1}{2}$ -oz. increment, and so on. The same fractional part of the stimulus is necessary in every case. As a rule, then, if the necessary physical increment is determined for one standard, a reasonably safe mathematical estimate can be made for other standards. For example, if with a 20-c.p. light 1 c.p. must be added for one to detect a difference in illumination, then, if a 100-c.p. light is used, a 5-c.p. increment would be required to give a noticeable difference. The increment is a constant fractional part of the stimulus.

Thus, in a given sense field, let us say, the least noticeable increase in the intensity of a stimulus is a constant proportional of the original stimulus. Equal sense distances cor-

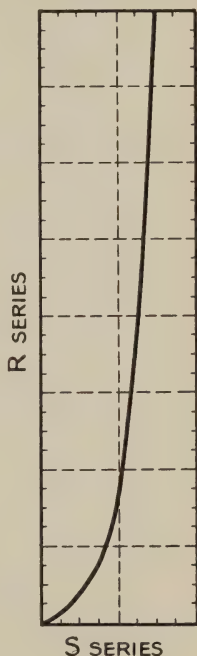


Fig. 48. — Diagram Showing the Nature of Weber's Law.

respond to relatively equal differences in the physical stimuli used. This law is called Weber's law. Weber's law has been shown to apply in the case of colors, brightnesses, pressures, tones, taste, and some subcutaneous sensations. The relation of the stimulus to equal sense distances is indicated, in principle, in Fig. 48, where R represents the stimulus and S the sensation values. It is seen here that if the S -series is arithmetic, the R -series is geometric, that is, if the S -series is represented by the numbers 1, 2, 3, 4, 5, 6, the R -series will be 1, 2, 4, 8, 16, 32. Weber's law holds true with middle intensities, but slight variations from it seem to appear near the threshold limen and the terminal limen. These apparent exceptions may be due to imperfect experimental technique; it is likely, however, that the sensory end organs are better adapted for middle intensities, which are normally used, than they are for the extreme intensities, which are infrequently used. For instance, in audition neither the very low and weak tones nor the high and intense tones are frequently experienced.

The physiology of sensory intensity. For a long time scientists have been puzzled by the apparent discrepancy between the intensity of the physical stimulus and that of the sensation it produces. If there is a loss of energy in the condition between the physical stimulus and the sensory experience, where and how does the loss occur? The facts associated with Weber's law offer a problem which should be solved.

For many years it was believed that the explanation of differences in sensitivity was to be found in the inertia of the sense organ and of the afferent nerve. Every receptor seems to offer some resistance to physical stimuli; the amount, as

we have seen, varies for different sense fields, and for the same type of receptors under different conditions. Visual receptors respond to weaker stimuli than do touch, and the stimulus limen of smell is much smaller than that of taste; besides, as in touch, the accessibility of the receptors affects the size of the limen. It is true that the stimulus limen is in every case due to the amount of energy necessary to arouse the receptors; but the assumption that the resistance or inertia increases somewhat in proportion to the increase in the intensity of the physical stimuli is false. Many years ago it was discovered that the all-or-none law applied to muscle fibers, that is, a single fiber, when stimulated, gives a maximum contraction or none at all. The weak or partial contraction of a large muscle is due to the stimulation and contraction of only a few fibers.

More recently it has been found that the all-or-none law applies to afferent nerves. Suppose, then, a physical stimulus is applied to a sense organ with just sufficient intensity and only long enough to effect a response; a nervous impulse of maximum intensity for that sensory nerve would pass centrally. If the stimulation of the sense organ is prolonged, by the application of a stimulus of constant intensity, a series of separate nervous impulses passes centrally over the nerve. The prolonged nervous activity does not consist, therefore, of a solid stream of impulses. After a single impulse is set up, a very brief interval of time elapses before another impulse can start. During this interval, which varies in length and which is known as the refractory phase, the nerve fiber is refractory, that is, for the moment another impulse cannot start from the same receptor. It is somewhat like the intervals between the dots made with a tele-

graph key. Although it seems very hard, if not impossible, to produce fatigue in a nerve, it is not unlikely that the refractory period, even if it is only about $\frac{2}{1,000}$ of a second in length, permits recovery sufficient to permit another impulse to be conducted over the nerve.

The number of impulses per second conducted over a sensory nerve varies considerably under different conditions; but we are here especially concerned with the fact that, within limits, as the intensity of the physical stimulus is increased, the number of the impulses becomes correspondingly larger. It is believed, therefore, that a close relation exists between the number of impulses per second passing along the nerve and the intensity of the sensation, for, as we have seen, a weak stimulus causes fewer impulses per second than does a strong stimulus. This may be one explanation for the fact that high tones are intrinsically more intense than low tones.

Let us turn to muscular contraction for another suggestion. A partial or submaximal contraction of a muscle is a result of the contraction of a few muscle fibers, while the maximal contraction is the effect of the contraction of every fiber in the muscle. It is believed that an intense stimulus not only causes more nervous discharges per second over a single afferent fiber than does a weak stimulus, but that the stimulus also spreads and affects a larger number of receptors. If the intensity of a small stimulus falling on the retina is increased, a larger area of the retina will be excited. Moreover, retinal sensitivity is higher in those areas where cones and rods are most numerous. In touch, thermal, electrical, and mechanical stimuli spread in various ways when their intensity is increased. The taste of bitter seems

more intense when the mouth is generally stimulated with quinine solution than when a very small drop is applied to the tongue. It is also believed that, in audition, loud tones are in part a result of the excitation of a relatively large number of fibers. It is not unlikely, then, that the explanation of different intensities of sensations of a given order and the explanation of Weber's law are to be found in several characteristics, including the differences in frequency of impulses, the relative number of end organs or receptors involved, the difference in sensitivity of receptors, and the afferent compound nerve which, like a telegraphic cable, may carry impulses of different levels simultaneously.

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CHAPTER IX

Image

IT IS a well known fact that one's thoughts consist of more than sensory processes. An adult almost never experiences sensation only. A pure sensory experience is, then, a very rare exception and not the rule. A tone, for example, very seldom appears alone, and a series of sudden noises is not merely a number of psychologically isolated and unrelated auditory sensations. Nor does a color, an odor, a pressure, or a taste occur by itself. As a rule, the tone is immediately attended by a visual image of a tuning fork; the noise arouses imagery of the metronome or a clock; the odor reminds one of an orange; the pressure is associated with a pencil; and the pain is instantly linked in thought with a physical irritant. None of these added or associated images has at the moment a sensory basis, for the corresponding sense organ has not been excited. A word, uttered orally, may immediately evoke visual and auditory images of Radio City; a scream may be attended by the images of a mangled child, a car, and the highway; or a continuous noise may bring into consciousness the image of an air liner.

It is also commonplace knowledge that one recalls visual images of streets, ocean liners, buildings, portraits, and Greek vases that one has seen, and operatic overtures that one has heard. Moreover, one builds up in one's mind novel

images, as that of a mermaid, a house, or a sonata which as such he has never experienced before. Furthermore, there are vivid dream images, and the illusions and hallucinations so common to patients suffering from abnormal mental conditions. In some instances of dreams and abnormal images the attendant sensory basis can be discovered; in other cases no sensory cause can be detected. In any case the psychological processes greatly exceed any known modes of sensory stimulation, sensation, or group of sensations. Then, what is the nature of the added or, more particularly, the imaginal processes?

Obviously, data arise out of mind itself and give what we have here called added or associated experience. An examination of the nature and of the types of images shows a close resemblance between the data of past experience and these imaginal processes. It may be said, then, in general, that the mind has the capacity to retain or to store up sensory experiences, and then later under given conditions revive them as conscious processes. For the sake of convenience, let us use a familiar figure of speech. The mind may be regarded, in this relation, as a plastic, impressionable substance upon which sensory experience may be etched and retained. The depth and permanency of such records depend upon many factors which vary greatly with the same individual, and also vary very widely with different individuals. Two facts must, however, be remembered in this connection: first, the mind is not brain as such and does not behave as physical substance in time and space; and, second, the retained sensory experiences are not stored up and kept intact and isolated from each other as shot in a bag. They may remain as vivid and clear processes, or they may become very weak

and unclear; and moreover, they are active processes which, by their very nature or through the laws of the mind, become associated with each other and with other mental phenomena. Undoubtedly they not only take a permanent place in the formation of ordinary thought processes, but also form a basis of so-called creative thought. But what is image?

Definition of image. Although an image is usually associated with other psychological processes, enough is known about the nature of image to justify a separate definition. It is the second of the three psychological elements. As such it is defined as a simple psychological process, which arises internally and has the indispensable attributes of quality, extensity, attensity, intensity, and protensity. This definition requires explanation.

Pure image is regarded as a simple, unanalyzable process. It resembles in its category the pure tone or the pure color in the realm of sensation. It is the experience only. Let us carry the analogy further. Image may appear, and usually does, as a complex imaginal state, just as tones appear in combinations when a string is plucked or an organ pipe is sounded. The image of a house, an overture, or a crash of thunder may be composed of several different parts so related as to form a psychological unit. A photograph, visually, is a complex of whites, blacks, and grays, whether seen sensorily or imaginally. The attributes or indispensable characteristics are the same as those specified for sensation, and they each play essentially the same rôle with image as with sensation. Image is usually more elusive than sensation; hence it is more difficult to detect these attributes even under ideal experimental conditions. But even a casual

observer, upon reflection, can identify and note the indispensable nature of some of the attributes. Recall a sound, a visual experience, or a touch experience; the sound will be tone or noise, the visual experience will be gray or color, the touch experience will be pressure, pain, or some other quality. Try again, and note the spatial nature of image. Each type of image will appear as extended spatially. Imagine a banana, a baseball, or, especially if you are neurotic, a severe ache or pain. The images do not shrink up into mathematical points. Bound up with meanings as such imaginal objects are, they nevertheless give us illustrations of extensity, and suggest that the imaginal experience would not exist without that attribute. Protensity, intensity or density, and attensity may likewise be considered essential to imaginal processes.

Image, moreover, arises internally, that is, out of mind itself. It does not require the presence of a sensory experience immediately associated with it. The only exception seems to be in kinaesthesia, and in this case the exception may not be a valid one on account of the confusion here with physiological processes which appear so easily and quickly. For example, kinaesthetic memory of a word is almost invariably accompanied by laryngeal activity, and imaginal pain is usually attended by some physiological change in the region where the pain is localized. The word "internal" must be considered, then, as referring to mind itself and not merely to some experience located in or arising from some sensory area within the body. It should also be remembered that the principle of mental projection applies to image, as well as to sensation and other thought processes. For instance, an imaginary pain is localized in some part of the

body, an imaginary tone seems to originate at one's piano, and the image of a burglar is located on the terrace near the study.

The qualitative nature of image. Qualitatively, as has already been suggested, image may arise as from any sense field. Ordinarily one thinks of images as belonging particularly to vision, and perhaps also to audition. Although for most people visual images are clearer and more numerous than are images in other fields, auditory, olfactory, gustatory, and tactual images do occur. Gustatory and tactual images seem to be much less frequent than visual and auditory images. It is obvious, therefore, that images have the same general qualitative characteristics that sensations have. The reason why images are qualitatively similar to sensation is to be found in the fact that images have their origin, ultimately, in sensation. As has been stated, the mind retains sensory experiences, and, in doing so, thus preserves the qualitative characteristics. An image of imagination, formed as it is of other images, is no exception to the rule. The similarity of the qualitative characteristics of sensation and of image is one cause of the ease with which observers make the error of taking image for sensation. In fact, under certain conditions image cannot be distinguished from sensation.

Evidence of the similarity of sensation and image. If sensation and image are defined similarly, and if under certain conditions they cannot be distinguished from each other, what actually is the difference between them? As a matter of fact, there is no primary difference psychologically. The definitions specify that sensation depends upon the immediate excitation of a sense organ, whereas image does not.

Image is generally less stable, less intense, less sharply outlined, and less definitely localized than sensation; but these are only secondary differences. The fact is that, descriptively, they are identical in so far as their primary attributes are concerned.

Suppose we resort to experiments for proof of their similarity. A large gray ground-glass screen was set in a panel resting against the wall of a laboratory room. Unknown to the observers, the screen opened into an adjoining room. The observer sat in front of the screen and projected upon it an image of a familiar object specified by the experimenter. The observer then described the image in terms of its quality, intensity, and other basic characteristics. In this way images of several familiar objects—an orange, a maple leaf, a banana—were projected and described. But the assistant experimenter in the adjoining room had a projection lantern and cleverly designed slides of each one of the objects which the observer was asked to imagine and describe. Following secret signals given to him by the experimenter, he projected upon the screen a very faint physical image of the object that the observer imagined there. The physical image was kept on the screen 50 per cent of the time, and 50 per cent of the time only the image of the imagination was there. Thus, the observer actually experienced image about one-half of the time and sensation the other half. Many observers were used, and no one of them, it seems, ever suspected the presence of the physical images. Moreover, the descriptions of the sensations and the images were almost identical. Under these conditions the observers did not know that they were experiencing sensation, despite the fact that the physical images at times appeared in an awkward position. If, then,

the images of imagination and those of sensation are descriptively similar, they would seem to be alike psychologically.

Experimental investigations may be made in other fields. When one listens to a faint tone, he cannot indicate when the sensation actually ceases; or if the tone is interrupted for a moment, the gap is oftentimes not noticed because it is filled in by tonal imagery. It is such imagery that makes it sometimes impossible to specify the exact moment a high tone from a violin ceases. In smell, if the observer is asked to describe a familiar odor, the reports will be about the same even though the air current contains the smell substance only one-half of the time. Touch also furnishes clear illustrations. Adjust an algesimeter so that the stimulus point will regularly exert sufficient physical pressure to arouse clear pain. After the instrument has been applied to the skin several times and the observer consequently expects to feel pain, secretly reduce the pressure to a minimum so that the end organ of pain will not be excited. Although no sensation of pain is aroused, the observer will report pain and describe it as sensory experience. The images of dreams are likewise so similar to sensation that they, at the time of their appearance, are believed to be real sensory experience. Psychopaths also have no doubt about the sensory basis of the various images that arise in their minds. Regardless of our attitude toward hypochondriacs or dipsomaniacs, the pain or the pink elephant may be very real to them.

In view of the numerous evidences of the similarity of sensation and image, it must not be understood that they cannot be distinguished from each other. Their secondary characteristics and their context ordinarily make the identification of sensations easy. As a rule, sensation is more in-

tense, more stable, more definitely localized, and more sharply outlined than image. Moreover, sensations usually appear in a context—that is, in a setting or conscious framework that is stable. Sensory experience also persists in time, in sharpness of outline, in intensity, and in its setting or context, and so may be examined or tested to establish its identity as sensation. On the other hand, the low intensity of images, their tendency to change and shift about, and their vagueness of context make them seem different from sensory experience. One's image of an orange, for instance, has the same primary characteristics as one's visual perception of an orange, but secondary factors prevent frequent confusion of one with the other. Furthermore, in normal conditions, as when one is awake, one constantly uses the sense organs and other means of checking and identifying experiences; but he cannot employ such methods in sleep, during delirium, and under certain other novel conditions.

The substance of image. Here again one must not make the blunder of assuming that mental data are elusive, mystical, intangible phenomena that have no real existence. To say that states of consciousness, including image, have no substance is too paradoxical to claim one's time. Image is as real as any other part of the mind. Then of what are images composed? What is the substance of images? The question can be answered by saying that the characteristic substance of image is essentially that of sensation. Let us take an illustration from vision. One projects a color image upon a gray screen or a piece of gray paper; what is it actually that is projected? At best, one can say that the substance is merely a color experience itself, having a given quality, a certain intensity, and so on. If the projected

image could be isolated from the screen on which it rests, it would perhaps resemble a negative afterimage of color projected in the air, say, about ten feet before one. The auditory image is tone- or noise-consciousness which may be so projected that it appears to originate in some physical object, or its localization may be indefinite. The pain image is likewise consciousness having the quality of pain which is projected by mind into some part of the body. Whatever, therefore, the type of image—memory image, illusion, hallucination, dream—and regardless of the general cause of its appearance, the experience is a fact of consciousness and possesses the characteristic traits of mental substance. Then, too, however composite the imaginal data of a given imaginal experience may be, and irrespective of the immediate association of the imaginal experience with sensation or its general imaginal and sensory context, the substance of image is present and must be treated or defined as experienced.

Types of normal images. As we have seen, pure images are processes of consciousness which arise out of mind, independently of any immediate sensory excitation. These processes may be simple or elementary states of mind; or, as is almost invariably true, they may be complex enough to embody components of several imaginal types at the same time. Moreover, much more frequently than not, images are attended by sensations arising from one or more sense fields. The visual image of an orange, for illustration, does not stand alone as an image of a certain quality having a given spatial extent. It is accompanied by imagery of its immediate surroundings or its background, that is, the quality orange no more stands alone utterly isolated than one can see a word on this page entirely apart from the white

of the paper. Furthermore, the image is usually attended by touch experiences arising, say, from the lips and throat. These accompanying experiences give a complex setting, or context, as it were, to the orange color. Now, the wide range of an individual's experiences makes the number of possible contexts for image very large. It is therefore not to be wondered at that images seem to appear in vastly different ways, for the variety of associations or contexts is almost inexhaustible. In view of such associations, processes, or experiences, any classification of images must be made in the light of their modes of appearance. Although we may safely assume that the essential nature of image itself does not vary, the modes of appearance of images do differ widely. It is understood, then, that the difference in types of images is conditional and not absolute. What are the types of images?

Afterimages. Positive and negative afterimages are produced, as we have seen, by sensory excitation which continues for a while after the physical stimulus has been removed from the sense organ. If one looks at the sun for a moment and then turns away, a disk of brightness and then perhaps a sequence of colors will appear; the retinal activity does not cease for a few minutes. Such afterimages, therefore, are not true images; they belong to the field of sensation. The only known exception is that of the visual negative afterimage which, for some unknown cause, may appear as an afterimage of imagined color. Such an image has been described by observers who know nothing of the nature of negative afterimages and who, it would seem, would be unlikely to report imagined negative afterimages. All sensory afterimages, whether positive or nega-

tive, immediate or delayed, must be classed as sensation, for they are coincident with and occur as a result of the excitation of the sense organs.

The memory image. In many respects a memory image is a replica or a reproduction of some previous sensory experience. It is somewhat like a photographic reproduction of a former experience, which is accompanied by recognition or a feeling of familiarity that identifies the experience as of the past; it would not be a memory image were the characteristic of recognition not present. On yesterday, one may have seen a human face, a new automobile, a brown thrush, a magnolia, a rose, a boxwood; today the visual memory image, clear and accurate in every respect including colors, may appear in consciousness; and one is aware through the attendant feeling of familiarity that it was experienced yesterday. The memory image of the boxwood, for example, is essentially the same in size, color, and texture as the original sensory experience; the feeling of familiarity is added. Likewise, one may remember a noise, a tone, or a series of words heard in a sequence. The clear note of a cardinal may reappear in memory as it was first heard. Memory images from other sense fields seem to arise less frequently and to be experienced as less intense and clear. The intensity, sharpness of outline or detail, quality, stability, and localization of the memory image vary widely with different people, and for the same individual under different conditions. Some people have almost no capacity for visual or auditory imagery; others have almost photographic minds which enable them, if they are artists, to reproduce an experience in detail.

It should be noted here that there are effects of time on

the intensity and sharpness of memory images. Within a few minutes after one has observed a face or heard a tone, the image may be clear and vivid; hours or days later it may become hazy and blurred, or even very obscure. If other imagery becomes associated with it, such substitution and modification may produce another image which scarcely resembles the original. Then, too, one may try to reproduce a memory image in a new context. In other cases the original context may be lost. When such changes occur, as is frequently the case, the memory image becomes obscure, unstable, and very indefinitely localized. Visualize the box-wood by the door in its normal setting, and then project it upon the gray wall. The first is easy; the second, difficult as it is, results in poor imagery accompanied by numerous movements of the eyes and other parts of the body. Some of us have watched students, on examination, squirming and looking at the wall as they tried to visualize a sentence on a certain page of the textbook. The weakened image and the effort to recall it in a novel context make a formerly clear memory image appear as vague and unstable.

It must also be stated that some sensory experiences become much more deeply etched in mind than others. A gruesome, horrible visual stimulus, or a weird, terrifying auditory experience may be so impressed upon the mind that it remains relatively clear. In such cases, the context is also likely to remain clear; and, since such observations are unusual, neither the image itself nor the context is likely to be disturbed by other processes. Nevertheless, in time even the most vivid images become less clear, less stable, less sharply outlined and less definitely localized; color becomes washed out and often seems to vanish, and the body of the image

becomes more vaporous and obscure until finally the residuum may be a vague feeling of familiarity only.

The memory afterimage. The memory afterimage is a state of consciousness similar to sensation, which appears immediately after a sensation and which may last from two to ten seconds. It so closely resembles sensation that it can easily be mistaken for sensory experience, for it is a kind of mental photograph of the sensation. The image is clear at first, and then fades out very quickly. It is an image similar in quality and structure to the sensation which it immediately follows. It, however, is not sensation, for it occurs in audition where sensory afterimages are unknown, and it may appear in vision when the visual stimulus is too weak or is presented too briefly to produce a noticeable sensory afterimage. It must, therefore, be regarded as a memory afterimage, or as a hangover of consciousness without any coincident sensory activity. One may observe this image very easily. Fixate for about one second an unfamiliar figure or an irregular line, then having a pencil and a sheet of paper ready, instantly look at the sheet of paper and undertake to trace the image that appears there. At first the memory afterimage is so clear that to trace it seems easy, but the image quickly fades and vanishes.

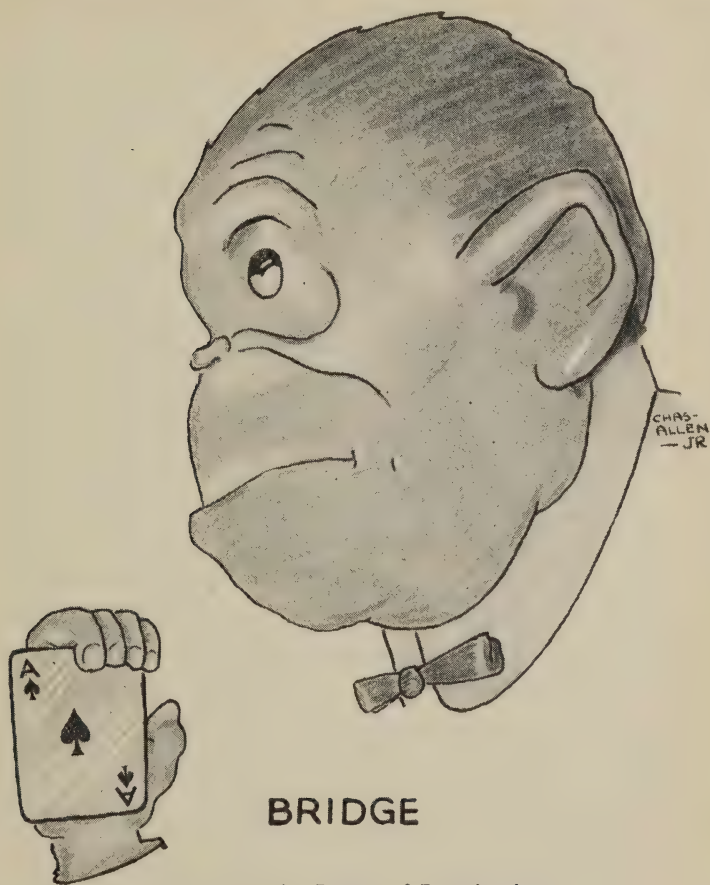
This type of image is much more commonplace than one first suspects, for very few people examine critically the mind or, for that matter, any other field. A few illustrations of the memory afterimage taken from everyday experience will suggest many others to the reader. Listen to the tick of a pendulum clock, to the tap of a drop of water falling upon the roof, or to the beat of a metronome; the sound does not vanish instantly but seems to linger for a

moment. When one takes dictation, his writing is several words behind the speaker and at the same time he hears each word that is uttered. It is a guess that there is a significant and basic bond by which different mental processes are linked together, but this is only conjecture.

The recurrent image. This type of image derives its name from its way of suddenly appearing in consciousness from time to time without any apparent cause. One hears a catchy tune played by an orchestra or a band, and then, later in the day, or even a week later, he suddenly realizes that the tune has been running through his mind. Who has not been haunted by the imagery of a word, a crude statement, or a mangled corpse? Such images burst, as it were, suddenly into consciousness both while one is awake and in dreams during sleep. Psychological associations leading up to them seem impossible to detect, although they may occur. The most plausible explanation of the perseverative tune is that it is touched off by sensory experience in the obscure level of consciousness. There are, for instance, rhythmical movements of the body when one walks which may touch off the image. Moreover, rhythmical sounds from the machinery near which one works, from the motor or the tires of one's car, from the blowing of the wind by one's study, or from any one of a score of other things usually in the fringe of one's consciousness may serve as stimuli which arouse the train of images.

The image of imagination. Stated in simple terms, an image of imagination is one which is formed in mind by a combination of other images, and which lacks the feeling of familiarity. The mind creates this new image by effecting a new combination of old imaginal data. It is, therefore,

new, and being new, it has few associations with other mental processes. This poverty of associations with other mental



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Fig. 49.—An Image of Imagination.

data, including sensations, other images, and affection, causes the aspect of novelty and the relative permanency of an image of imagination. Imagine, for illustration, on a page before you a creature having the body of a man and

the head of a donkey; the strange image persists, is stable, and may be examined. Imagine a banana lying on the desk; the image is so complete in detail that its color, texture, size, and tridimensionality may be perceived easily, and it is sufficiently stable to permit a long examination. If the image of imagination disappears and, later on, is recalled, the image may seem familiar and so, technically, should be classified as a memory image; nevertheless the recalled image is similar to the original image of imagination.

In many instances, despite popular opinion to the contrary, the passage of years does not seem to modify an image of imagination. Such an image of a unicorn has not changed in shape or position for fifteen years. The images of a harbor, an airplane, and the crest of a mountain have likewise persisted in retaining their original features. Such images seem to resist modification, even when it is realized that they in no way correspond to the places or objects in question. An image of Broadway at 32nd Street was built up twenty-five years ago; despite a hundred visits to that place and the knowledge that the image of imagination is in no respect correct, the image suffers no appreciable readjustment. At first this seems strange, but in reality it is not so; after all, there is very little to interfere with the image itself. Since it was constructed of bits of imaginal experiences, it is not intimately tied up with sensation, perception, illusion, hallucination, and other conditions which would effect in it such changes as occur in other conditions of thought. This characteristic of permanency is invaluable to creative artists. A composer may work furiously to make a record of a symphony which his imagination has created,

but the very nature of the image of imagination permits him to make the musical record. An artist may thus paint an imaginary scene, and a sculptor may shape a block of marble until it corresponds to his image. The image of imagination, then, is a basis of invention and creative art; if mind lacked this trait, the amount of progress man could make is problematical.

Habitual images. Many concepts or abstract ideas, when they appear in consciousness, are regularly accompanied by certain types of images. With many people, one abstraction consistently tends to produce one type of image, and another abstraction a different type of image; so it may be said that certain forms of thought habitually arouse certain types of images. Examples of habitual images are numerous. With one observer, the concept justice is always attended by a visual image of a lady, blindfolded and holding a pair of balances. The abstraction truth is personified through visual imagery. Such words as war, power, mercy, evil, death, weakness, and victory tend habitually to produce in the mind of a given person their respective habitual images; and a Wagnerian overture invariably calls forth for some of us a given series of visual images. The habitual images in several respects resemble the images of imagination. In many instances the images were created and used to clarify abstract thought. Hence, frequently they become intimately associated with certain concepts and ideas which one uses.

Tied images. Every one has noticed that a mere sketch or outline of a familiar object is sufficient to produce a complete psychological image of the object. The sketch of the framework of a box consists only of black lines forming the frame of the object; but one may see the planes as filled in

with an almost imperceptible, thin, filmy, glassy, semi-transparent substance. The top only is open. It is image tied into the sensory portion of the perception that transforms the sensory experience into, say, a glass receptacle used to preserve biological specimens. If you examine carefully a block letter, you will discover that the black lines

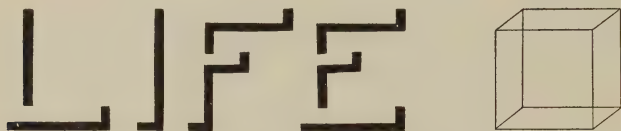


Fig. 50.—Tied Images.

form only a small part of the letter; but the mind projects the image substance into the framework and transforms it into a solid letter. Tied images are frequently used in cartoons and advertisements. The cartoonist or artist, with a few cleverly placed strokes, gives only the lines necessary to suggest the figure, leaving it to the observer's mind to supply the remainder. If the imagery is properly projected, the object immediately stands out in clear perspective. Tied images are not restricted to vision; they may be associated with experience in any sense field. In audition, one may hear clearly a small part actually omitted from a familiar orchestral production, just as an inexperienced proof reader may see as spelled correctly a familiar word from which a letter was omitted or in which letters were transposed. Using, as they do, the sense of touch, the blind do not have to examine every letter of the Braille type as the fingers glide over a line of familiar subject matter; imagery fills in gaps which may occur.

Memory overlay. We have shown how the mind projects image substance into a mere outline of some familiar perception and thus makes tedious, critical examination unnecessary. Memory overlay, in many respects similar to tied image, is the tendency of mind, during uncritical moments, to project upon a familiar sensory stimulus such imagery as may be necessary to make the stimulus conform to conditions which it normally possesses. Illustrations will make the matter clear. Who has not stooped to pick up a dime, and then had the object become a small disk of paper or tin just before the hand grasped it? The mind had laid the silver quality and the engraving upon the object. A coal pile is seen as uniformly black; snow appears as uniformly white; and grass is observed as uniformly green until one examines such objects critically; then it is not possible for one to find in such familiar objects a section one foot square which does not exhibit wide differences in quality. One is accustomed to silver candlesticks on the dinner table; he experiences silver when transparent glass candlesticks are substituted. A rose is left on a desk; the pink and green and the wax-like texture of the bloom and foliage are observed until one discovers that it is an artificial rose, whereupon the colors become washed out and the smooth texture is replaced by the lines of the threads of cloth. The visual overlay always seems to vanish when a critical attitude is assumed. The overlay is so pronounced, however, that the amount of brightness or color added can be measured with some degree of accuracy.

It must not be thought that memory overlay occurs only in vision. It appears perhaps just as freely in other sense

fields. In audition the observer may add tonal quality to a familiar musical number; and when every note is equal in physical intensity to every other, some of them will be heard as more intense than others. The odor of eau de Cologne may be had from an odorless liquid so long as the observer actually thinks the bottle contains perfume. An artificial rose may be fragrant until a critical attitude develops. The taste qualities of foods and medicines change when one's attitude changes. For example, a stall-fed puppy was characterized as delicious so long as the dish was thought to be wild game. In the field of touch, a bottle of water, colored to resemble mercury and labeled mercury, will seem a little heavier than it is after the observer discovers the misrepresentation. The weight of two boxes will be unequal if the observer actually believes one is heavier than the other. Pressure is frequently overlaid with pain when one believes that the stimulus is sufficient to produce pain.

It is obvious that imaginal overlay occurs in many sense fields, and plays an important rôle in both sensory and perceptive experience. By virtue of its influence, sensory experience tends to assume fixed patterns and to establish definite standards in the various sense orders. In an uncritical attitude the standard seeks to exert its influence, even to the extent that one not infrequently sees what he looks for and hears what he expects to hear.

Abnormal images. Abnormal imagery differs from the normal only in its mode of appearance. In some cases the associated images are excessive in number and are unusually vivid, while in other instances the sequence is unusually bizarre and persistent. In every case, however, the substance of abnormal imagery does not differ from that of normal imagery. The sequence may be as bizarre as a page of inco-

herent sentences, but the sentences are after all composed of words, and the words are in turn made up of the letters of the alphabet. Here again a few illustrations will serve our purpose.

Illusions. An illusion occurs when the psychological experience does not conform to the sensory stimulus which arouses the experience. In the case of an illusion the mind adds something which effects a metamorphosis, sometimes to the extent that the physical stimulus appears to be warped to such a degree that the stimulus object is almost lost sight of. Linear illusions are commonplace. Architects, civil engineers, and artists are familiar with this influence upon the perception of size, direction, and distance. Every normal individual experiences them. Illusions are classed as abnormal imagery when extreme distortions of sensory experience occur. For instance, when one is in a state of anxiety a weak tone is transformed into the ringing of the telephone; in fear, the faint noises made by a mouse become the heavy tread of a horrible beast. Cutaneous irritation, especially when caused by drugs, may be perceived as crawling insects which the patient tries to brush off. In some cases the weak ringing in the ears may become the sound of a bell. Definitely psychopathic individuals often suffer extreme forms of illusion. To them, pieces of plain paper become money, ordinary sounds are heard as human voices, and a faint odor becomes a poisonous gas.

It is clear that the influence of illusions is considerable. They must be recognized and reckoned with in many fields of normal thought, while in abnormal psychology they occupy a primary place. Moreover, whether normal or abnormal, they furnish an index to mental data and to the behavior of mind.

Hallucinations. Hallucination, by definition, is imagery which arises independently of any recognized sensory experience, and which is so vivid that it is mistaken for sensation or perception. It is probable that a hallucination has a sensory basis, either immediate or remote, but one is unaware of it at the same time the hallucination occurs. A hallucination may be experienced by normal individuals as well as by abnormal ones. When one is in a condition of mental strain or sudden exciting circumstances, vivid images, such as those reported by patriots and saints, may be had. Abnormal people are usually affected by hallucinations which may arise from one or more sense fields, and which may be pleasant or unpleasant in affective quality. The patient may see an enemy or a stack of currency, hear conversations, have foul tastes, and suffer pains. The dipsomaniac, when suffering a condition of delirium tremens, may visualize snakes crawling toward him, see and feel a mother cat and her kittens rubbing against him, or hear devils mocking him. A hypochondriac suffers excruciating pain or some other imaginary malady. Opium, hashish, mescal, and other drugs produce vivid images; and high fever is not infrequently accompanied by deliria. In some cases, the images which the abnormal individual suffers are so real and persistent that, in his efforts to escape them, he becomes dangerous to himself and to others.

Dreams. Dreams are states of consciousness that appear during a condition of sleep. The state of sleep is usually not profound; the imagery is realistic; the sensory stimuli, if present, are very rarely, if ever, recognized at the time of the dream. The imagery which comprises a dream may appear in normal sequence; or, since in sleep one lacks the

critical control which the sense organs permit when one is awake, a dream may be grotesque, incoherent, and generally ridiculous. In a dream one may reproduce past experience with remarkable accuracy, solve a problem in mathematics, give an address, converse with a friend; or, on the other hand, one may find himself improperly dressed at a formal dinner, discover at church that he is without his shoes, or undergo a state of terror as some beast is about to kill him. As already stated, during sleep one does not impose normal control, hence the various normal and abnormal sequences of images.

Frequently, if not always, the dream consciousness is started by physical stimuli of which one is totally unaware during the dream and which one may or may not discover when one awakes. Enough evidence has been obtained to show effects of stimuli. For example, pressure on the forehead may be followed by a dream of being struck on the face in a quarrel. Cold water sprinkled lightly on the face may arouse a dream of a rainstorm. Cold applied to a foot may be attended by a dream of walking barefoot in the snow. The odor of smoke is oftentimes followed by a dream of a burning house. If an arm or the head slips from the pillow, one may dream of falling. Slight pressure experiences, probably associated with joints and muscles, are adequate to make one dream that he is floating above the ground in spite of gravity. Indigestion needs only to be mentioned to indicate the frequency with which it provokes dreams. No one can safely predict the type of dream that will follow a given stimulus, but one is reasonably safe in assuming that sensory stimuli are the direct or indirect cause of most of our dreams.

The only strange feature of dreams is to be found in the distorted structure which they so frequently exhibit. But, however novel such associations seem to be, the data of dreams are related to the past experience of the individual. One dreams nothing absolutely new. Many things influence one with respect to the type of dream he is likely to have. As we have said, certain stimuli, as cold, may produce dreams about snow or cold rain. But there are other influences. One's recent vivid psychological experiences compose no small percentage of his dreams. Old intense experiences, deeply impressed upon memory, frequently arise. Moreover, bitter disappointments, fears, and hopes seem to play a large part in dream consciousness. For instance, disgraceful or shameful conduct is usually so intense emotionally and reappears so often in memory that it is likely to appear in dreams also. Suppressed desires and unrealized wishes likewise, and perhaps for the same reason, find expression in dreams, just as they do in flights of imagination. Sex, as an emotional force, plays a part; but Freud has undoubtedly caused undue emphasis to be placed on this part of the field of dreams. Some suspect that many of the strained and unwarranted interpretations of dreams in terms of suppressed desires are themselves a result of suppressed desires. Dreams are too diverse in their nature and too varied in their contents to be reduced to any one basis of desire, whether that desire is suppressed or not. One had as well say that all thought can be reduced to one type of motive or purpose.

Synaesthesia. This abnormality, perhaps about as frequent in occurrence as partial color blindness, is the definite tendency of the subject to experience sensation in one sense

field, when the sensory stimuli and sensory experience occur in another sense field. For illustration, auditory stimuli produce not only sensations of tone, but also sensations of color; one hears the tone and sees blue. In terms of pitch numbers, the following reports from one subject are interesting: a tone as of 65 v.p.s. produces dark brown; one having 600 v.p.s., dark blue; one having 4,000 v.p.s., green; one having 12,000 v.p.s. and above, gray. Colored hearing, chromaesthesia, is the most common type of synaesthesia, but other forms have been reported. In some cases, sounds produce sensations of touch; in others, taste; in others, smell. In rare instances, stimuli of light produce sensations of sound. There are also colored tastes and odors.

One immediately thinks that synaesthesia is nothing more than unusual, persistent associations of images with sensation, that is, that synaesthesia is nothing more than perception or meaning. Such may be true, but the evidence seems to deny the validity of that claim. Re-examination of cases after a period of from seven to fifteen years showed a persistence and exactness of associations which, under the circumstances, would seem unusual in perception. Moreover, a most peculiar fact is that, in the case of one subject who experienced *g* as blue, *a* as yellow, *c* as red, and *f*# as blue-green, the first law of color mixture obtained; a mixture of *g* and *a* or of *c* and *f*# produced a sort of gray. Vivid perception does occur, but it probably does not explain synaesthesia satisfactorily.

The explanation of the cause of synaesthesia is still highly theoretical. It is generally explained in terms of short-circuiting of sensory fibers, or of abnormal association of sensory areas of the cerebrum. The actual cause is unknown.

The place images occupy in thought. It may not be out of place here to mention the rôle image plays in thought. We have seen, however, how it has its origin, directly or indirectly, in sensation and how it closely resembles sensation. It has also been noted that mind not only retains the images produced through sensation, but that it also combines old imaginal data to produce new images. These new images are retained, and they too may be combined with themselves and others. Thus, imagination, a means of acquiring new mental data, may go on. Moreover, as we shall see later, image plays a large part in perception or meaning. Were it not for image, sensory experiences would probably stand alone as almost isolated experiences of the moment; however, with images lawfully functioning, mental growth and many other indispensable traits of normal human thought are possible. How images become associated with each other and with sensation we shall discover in the examination of perception.

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CHAPTER X

Affection

AFFECTION will here be regarded as the third mental element. There is, however, no more controversial subject among psychologists than affection, and the plain treatment given in this chapter will probably not meet with universal acceptance. It is, therefore, to be clearly understood that, especially with respect to a subject about which there is so much ignorance and so little agreement, more information and a clearer presentation are welcome. The primary purpose of this discussion is, first, to strip the subject, at least in part, of misleading concepts, and, second, in some measure conditionally, to point out the probable nature of the affective process and the necessity of studying it descriptively in the light of its actual, inherent nature.

Some types of confusion. As has been pointed out, it is difficult to discover another field in which so much confusion of thought occurs. Not only is there vast disagreement in the literature and elsewhere about affection itself, but the very language we use has a wide range of meanings. The words feeling and affection are used as synonyms. We employ the word *feel* in speaking of touch experiences, conditions of health, opinions, emotional states, and so on. The clay feels wet, the ruler hard, the reptile clammy, the wind cold, the water hot, the muscle sore; and "I feel that

the situation is perilous." One also feels happy, sad, uncertain, urged, restrained, a sense of right and wrong, and duty. Various forms of the word *feel* are used to characterize every type of experience from ordinary touch experiences up to refined ethical concepts; and the variety of confusion of meanings and interpretations does not end here.

Moreover, the average individual habitually thinks of feeling or affection in terms of social relations. He means the mood or attitude that he has with reference to other people, the love he feels, his sense of loyalty, and what not. No small percentage of people regard feeling as a peculiar spiritual endowment, and interpret conditions of feeling or emotion in terms of some mystical, spiritual endowment, or manifestation. Since feelings cannot be localized and examined except with the greatest difficulty, it is to be expected that the common-sense discussions of feeling would be what they are. The problem here is even more difficult than that of describing image. Images, for example, become vague and much of their residua disappears swiftly in thought; in consequence, the average person never suspects their presence in his processes of reasoning. For him, thought is just thinking. Similarly, feeling becomes for him an intangible, mysterious, mystical, perhaps spiritual part of his life. He takes it for granted, often misinterprets its nature and its place in thought, and may act rationally or irrationally as a consequence of its influence.

Another flagrant blunder is that of the stimulus error. All too frequently, as has been stated, the feeling is referred to the stimulus object. The Beethoven sonata is pleasant, the coffee is delightful, the dress is lovely, the hostess is charming. By these, many things are meant. But the fact

that one is oneself the experiencing individual, and that the feeling processes are a part of one's consciousness is overlooked. For instance, it appears that in much of the experimental work it is the quinine, the salt, the *C* minor, the sand, or the blood that is called pleasant or unpleasant. One might as well attribute cold to ice, sound to the tuning fork, or joy to a tree in autumn. The stimulus to feeling is no more the feeling than the sound waves are the tone. Besides, as a matter of vast importance here, the stimulus error obscures the affective process so completely as to make observation almost impossible.

Feeling and emotion not identical. It needs to be noted, moreover, that feeling or affection and emotion are not identical. Affection, like sensation and image, is an elementary process; emotion, on the other hand, is a mosaic, as it were, of sensations, images, and affective processes. An experience such as joy, sorrow, anger, disgust, hate, anxiety, or fear includes, as we shall see in the discussion of emotion, a vast amount of sensory, imaginal, and affective experience; and these psychological states are accompanied by multifarious bodily changes of various degrees of intensity and influence. Affection is only one part, the feeling component, of the complex emotional state. With respect to feeling, during the course of such a heterogeneous condition of consciousness as exists in the case of emotion, one can by introspection hardly do more than discover that the emotion is pleasant or unpleasant. Work in the field of emotion, which includes an investigation of bodily changes, must not therefore be confused with efforts to describe affection.

Experimental errors. The old experimental work was frequently crude and misleading, and was filled with such errors as one would naturally expect in a new and difficult

field. The sensory stimuli, designed to arouse feeling, were too intense; consequently emotion developed. As is now well known, a putrid odor, the sight of blood, biting a lump of sand concealed in food, a ghastly photograph, or a shrill sound is likely to produce emotion. No observer could make accurate observations of affection during, for example, a condition of nausea, or while sandpaper was rubbed against the back of his neck; the best he could do under such circumstances was to report gross experiences. Moreover, when later on weak stimuli were used, errors were committed through the misleading instructions given to the observers. For illustration, in an experiment known as the method of impression, two colors were placed behind two juxtaposed windows in a cardboard screen and exposed simultaneously; the observer was instructed to report which member of the pair was the more pleasant. Or two tones were produced, and the observer indicated which tone was the more pleasant. Two blunders are here obvious: first, it was assumed that the affective process was present, and, second, and of more importance, the observer was made a "feeler" and so was not asked to isolate and describe the affective process as such. To say that one experience is more pleasant than another is easy; to describe an experience is as difficult as it is essential to scientific method. It seems that, until recent years, no observer was asked to describe affection as such; his reports, therefore, dealt only with such facts as the occurrence of feeling, its quality, and its relative intensity as related to some object or in association with some generally complex mental state.

In fact, psychologists generally assumed that affection lacked the attributes of extension, clearness, and intensity, and that it was therefore intangible, elusive, and evasive;

affection would not therefore stand up under observation. It was thought that the moment one undertook directly to observe affection as such, it would vanish. Experiments performed since 1920 seem to have avoided many errors of the earlier work, and to have given descriptive information concerning the nature of affection itself. It is to a brief summary of this work, especially that of J. P. Nafe, that we now turn.¹

Recent experimental investigations. In this work it was assumed, as an experimental hypothesis, that the affective process does exist; that it is an element of consciousness, associated with sensation or image, or perception, but distinguishable from them; and that, under suitable conditions, it would stand up under observation. It was understood that if, on the other hand, it will not withstand observation, it cannot belong to the subject matter of descriptive science. The utmost care was employed in an effort to eliminate errors in the experimental technique. Intense stimuli and emotional states were avoided. According to the tradition of the laboratory, during the experiment no observer was permitted to discuss the experiment or learn of reports made by the other observers. The instructions given to the observers were designed to ask for a complete description of the experience produced by a sensory stimulus, with the hope that affection would be included. If it were included, then its various characteristics, as stated descriptively, would be noted.

The results. The results of this unique and pioneer investigation should not be considered complete and final in

¹ Published in the *American Journal of Psychology*, XXXV (1924), pp. 507-544.

the field; they are, nevertheless, suggestive, and they will doubtless stand the test of further experimental examination. What, in general, are the results? For our present needs a brief summary follows:

1. The affective process does withstand observation. It stands up under conditions necessary to scientific examination. Both the highly trained and the relatively inexperienced observers found no great difficulty in discovering the affective increment. At times it was the focal or dominant part of consciousness, permitting itself to be attended to almost exclusively; the sensation was, however, never entirely absent under such conditions but seemed to be in the fringe or obscure level of consciousness. The affective process never appeared by itself, but always, whenever it appeared, it was coincident with sensation or image, or arose as a component of perceptive experience. But, when the observer did not try to attend to two things at once, that is, when he let himself become "set" to attend to the affection itself, the affective process frequently became, as it were, the substance of the clear area or level of consciousness. Apparently, then, affection does have the attribute of attensity, for, under suitable conditions, it does become clearly palpable and stands up under observation. The old investigations did not permit its isolation or fractionation from other thought components.

2. Affection, although it appears coincidental with sensation or image, is not identical with either of them. Neither sensation nor image is intrinsically affective. The affective increment usually arises later in time than the sensation, but it never outlasts the sensation. The sensation may be non-affective; or it may be intermittently affective and nonaffect-

tive or alternately pleasant and unpleasant, according to the failure of the affective process to appear or because of the appearance of first one affective quality and then the other. Moreover, the localization of sensation is frequently so different from that of affection as to warrant the assertion that they are not of the same psychological category. In general, sensation is easily localized, whereas affection is not. Perceptive reference to the region of the abdomen or to that of the neck and shoulders may occur, but, even so, the affection does not necessarily coincide in place or extent with the sensory experience arising from muscular contractions in these areas. The organic changes reported seem, then, at this time, to be neither constitutive of affection nor covariable with it. Again, the terminology used in descriptive reports of affection seems to belong to touch; but it must be remembered that no technical terms have been coined exclusively to describe affection as such. Moreover, although the observers used the language of the field of touch, they were reluctant to do so because they felt that touch and affection belong to different modalities of experience.

3. There are only two qualities of affection, namely, pleasantness and unpleasantness. Whenever affection appears, it is, in quality, either pleasantness or unpleasantness; it is never intermediate and never a blending of the two qualities. Qualitatively, the experience, in the case of pleasantness, is characterized as bright pressure and tickle. The descriptive reports of pleasantness contain such words as bright, sparkling, dancing, shimmering, mild, misty, light, airy, thin, smooth, like goose flesh, like effervescence. The experience, in the case of unpleasantness, is characterized as dull pressure, or a touch quality lying between dull pressure

and strain. In groping for adequate terms, the observers described unpleasantness as dull, dead, drab, sinking, harsh, thick, cold, leaden, like dull strain. As has been stated, the observers demurred at using the terms generally employed to describe touch qualities; they did not believe they were describing a touch experience, but no other language was at their command.

Moreover, with respect to their mode of appearance, pleasantness and unpleasantness are definitely unlike and incompatible. They never appear together, and they never to any extent become mixed. They may alternate quickly, but there is no evidence of coincidence. For instance, a sensory experience may at first be pleasant and then unpleasant, but it is never at the same time both pleasant and unpleasant. Unlike complementary colors, pleasantness and unpleasantness do not appear alongside each other; and, unlike noncomplementary colors, they refuse to mix and produce an intermediate.

4. In intensity, the affective process is inherently mild or weak; it is never very dense or intense. The intensity of a given affective experience may vary, and one experience may be more intense or less intense than another. Moreover, if one thinks of the affective experiences in terms of structural patterns, the two qualities are unlike. For instance, pleasantness seems to be less dense at its center than toward its periphery, while unpleasantness is generally more dense at the center than elsewhere. If the intensity of either pleasantness or unpleasantness is increased very much, the experience becomes perceptive.

5. The affective experience is intrinsically spatial, although the limits are so indefinite that no exact boundary or

outline can be specified. The experience is, however, positively of a voluminous nature. The extent or volume is not fixed; one experience may be more voluminous than another, and the same experience may contract or expand with a variation in its intensity. In general, pleasantness is more voluminous than unpleasantness. Pleasantness seems to be relatively large, and it appears to increase in size as its intensity is increased; while unpleasantness is usually not so extended and decreases in volume when its intensity is increased.

6. Every affective experience is temporal, that is, it lasts for some period of time. As has already been pointed out, it never outlasts the sensory or imaginal experience with which it is associated. It may appear for an instant, and then vanish; its course may be intermittent; in quality, it may be, alternately, pleasantness and unpleasantness. No limits of duration are fixed for either quality. The one temporal difference between the two qualities seems to be found in the fact that the pleasantness arises gradually though quickly, while unpleasantness appears full-fledged.

Thus, it would seem that affection is a third type of mental process or element. Sensory or imaginal experience may occur without it, and, therefore, be neutral or nonaffective; when, however, the affective increment appears, the total experience is different from the sensory or imaginal component. The affective increment gives the tone or color of the feeling to the total psychological state, a quality which mental states, whether simple or complex, could not have without the existence of affection.

Affection and association. It has been shown that affection never appears except as associated with sensation,

image, or some other mental state. It was stated that a given sensory or imaginal experience may be intermittently affective and nonaffective. Such facts must be understood to mean that the appearance of affection or its association with other experience is an unpredictable or haphazard matter, for no such condition of uncertainty and vagueness exists. The law of association, which will claim our attention later, applies to affection perhaps just as strictly as it does to other mental data. Let us cite an illustration.

The method of impression. The method of impression is a simple experiment by which one discovers the type of affective quality, if any, associated with each one of a series of stimuli of a specified order. It also reveals the tendency of such associations to become permanent. The method of paired comparisons is the most generally used form of this experiment. In it a simple form of apparatus is used. Two windows, located beside each other and having shutters which may be opened simultaneously, are cut in a large gray cardboard screen. A series of 50 color stimuli, including the primary colors and intermediates and numbered 1 to 50, is prepared. The mode of presentation is arranged so that each stimulus will be shown with every other stimulus, that is, 1 will be shown with 2, 3, 4, 5, and so on up to 50, and 2 with 3, 4, 5, 6, and so on. The observer sits in front of the screen and, when a pair of colors is exposed, merely indicates which member of the pair is the more pleasant. At the close of the experiment the record will show a number of affective choices; the most pleasant colors will have been preferred a large number of times, the mildly pleasant a few times, and the indifferent stimuli scarcely at all.

The experiment may then be repeated, and the observer

now asked to specify the more unpleasant member of each pair. In this case, at the end of the experiment, the very unpleasant will have been preferred a large number of times, the mildly unpleasant a few times; and so on. If the results are then plotted, it will be seen that the two frequency curves made from the choices obtained from the two experiments are almost the opposite of each other. This fact shows the

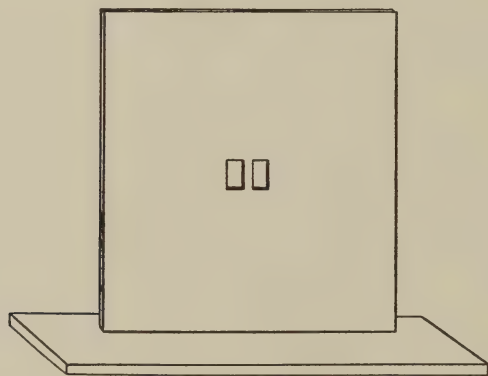


Fig. 51.—Apparatus Used in the Method of Impression. (Colors are exposed simultaneously in pairs through the windows, which are opened automatically for about one second.)

persistence of a given affective quality in its association with a given color stimulus. Moreover, if the experiment is repeated one year or five years later, the results will show a close similarity to the earlier reports, which suggests the permanence of the association of an affective quality with a given type of sensory stimulus.

It would seem, therefore, that one's affective experience in general becomes established by association. Of course there are stimuli which are nauseous and repulsive; there are also some colors, for instance, which seem to provoke unpleasant-

ness. In such cases the affective association occurs irrespective of one's training. But, despite the influence of stimuli as such, it may be inferred from this experiment, as it is suspected from casual observation, that, for a given individual, the affective quality of a given familiar stimulus is determined largely by his training. The associative tendency may persist long after the incidents occurring at the time of the formation of the bond have been forgotten. For instance, one does not like the color yellow. He does not know why, for his memory of some unpleasant experience which occurred during his childhood has been forgotten. While his memory of the incident is lost, the affective association with such a stimulus persists. Then, too, old associations may persist to cause one to like or dislike certain things. For example, one may be pleased by a book, by roses, or by trees because of earlier associations of pleasantness with them. On the other hand, one may dislike orange juice because he took medicine with it; and lilies of the valley may provoke unpleasantness because one has experienced them at funerals. In this way one's thoughts become habitually colored with feeling, and it is thus that one's so-called likes and dislikes become firmly established. Moreover, in all probability, such subtle affective associations form no small part of such experiences as the feeling of familiarity, recognition, and intuition.

It was stated in the preceding paragraph that certain sensory experiences, regardless of one's training, are usually accompanied by one type of affective quality. Thus, there is normally a condition which is somewhat independent of prior experiences but which is not a contradiction of the claim that the law of association plays a significant rôle in

the establishment of affective bonds. For instance, the affective quality is influenced by the intensity of the sensory stimulus. A weak stimulus may be attended by pleasantness, but an increase in the intensity of the stimulus may cause unpleasantness to appear. Saturated colors, as a deep blue, are usually more pleasant than those of poor chroma. Certain color combinations, as pairs of complementary colors, are likely to be pleasant, while colors that clash usually produce unpleasantness. Certain odors, as flowery, fruity, and incense, are generally pleasant, while putrid and scorched are as a rule unpleasant. Intense bitter and extremely sour tastes produce unpleasantness. Neutral pressure, tickle, and smooth pressure may be pleasant, but pain and ache probably induce unpleasantness. In esthetics, shape, contour, symmetry, and balance obviously induce pleasantness. It is clear that many such experiences are complex and definitely meaningful. Of course, meanings and other factors may appear to violate the general rule that some types of sensation tend to be accompanied by pleasantness and others by unpleasantness. A pain, for example, can be pleasant, just as a grotesque structure may be amusing; the meaning so modifies the sensory experience that the influence of the sensory experience itself is superseded by that of the perceptive complex. This is generally true; some types of sensation normally tend to arouse pleasantness, and other types unpleasantness; training may modify greatly these modes of association.

It should also be noted here, as well as in a treatment of emotion, that the appearance and intensity of feelings vary greatly with different individuals, and with the same individual under different conditions. One's life may include

severe and extreme types of personal experiences. For example, there may be glandular abnormalities, which greatly affect the patient. And there may be such discipline as leads to the formation of deep-seated prejudices. Scores of such things produce vast differences in the affective tone of people.

Finally, it must be remembered that feeling is definitely an integral part of mind. It is as much an existential fact as is sensation or reasoning processes, and must be so regarded.

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CHAPTER XI

Perception: Definition

IT WAS stated that the descriptive psychologist, like the chemist, undertakes to isolate the psychological elements and describe them. In the preceding chapters, we have endeavored to specify the basic characteristics of sensation, image, and affection—the three psychological elements. Since an adult, and perhaps a child as well, almost never experiences a psychological element alone, the experiences that we have been describing were arrived at by introspective analysis; that is, the observer, under the best conditions that could be established, let himself be attracted as completely as possible by the sensation, or the image, or the affective process itself, thus stripping that part of consciousness as nearly as possible of all associated processes until reasonably accurate observations of the process could be made. For example, a tone, as such, was caused to occupy the clear level of consciousness; or, again, since affection never appears alone, in the case of a sensation attended by affection, the sensory component of the total experience was so ignored or receded so completely into the obscure level of consciousness that the affective process itself was discerned and described.

These elements were said to be simple. They were treated as though they stood alone in somewhat isolated form. But

mental processes, perhaps much more so than physical elements, dislike isolation. They detest isolation as strongly as nature abhors a vacuum. They are active, and they almost invariably associate themselves together, forming fusions or compounds. When a sensory or imaginal experience has other processes associated with it, meaning arises. The yellow means a pencil, the black means a pen, the tonal sensation means a piano, the fruity odor means a lemon, and the bitter taste means quinine. Instead of simple experiences, we have, therefore, complex states of consciousness. Our problem, then, becomes that of analysis in order to determine the components of the compound.

The difficulty of psychological analysis. Now, the task of analysis is not an easy one. There are many errors that may be easily made. The stimulus error is a pitfall common to most efforts at introspection. The observer, in making this error, describes the physical stimulus or substitutes it in his thought for the actual psychological processes that compose the total experience. One is, therefore, likely to let himself think of the physical apple instead of the taste, the odor, the color, and the touch experiences that constitute the psychological complex; or he lifts a baseball instead of noting the pressures and strains in the wrist, the arm, and the throat. Psychologically, an orange, a pen, a tree, a book, a desk, and a radiator are meanings; they are psychological compounds; they are each, let us say, sensory experience with which other experiences—secondary sensations, secondary images, affective processes—are associated. Our examination, then, must be confined to the mental processes rather than to the physical object. Another difficulty will be found in the fact of incomplete analysis.

Meanings vary in the cases of different people. So many associations may be made that it becomes almost impossible safely to say that a given sensory stimulus will produce a certain meaning, or to assert that a given meaning is composed of certain associated processes. Mind is so complex and training so diverse with respect to different people, that in our study here we shall confine ourselves to a presentation of general facts. This statement must not be misinterpreted. Certain principles do apply in meaning, even if one cannot say that the data in a given instance are of a certain type only. Our present study will be stated very simply, perhaps so simply that to an advanced student of psychology it will appear unduly naïve and incomplete; but it is our purpose primarily to show the general nature of perception rather than to risk confusing the introductory student with a mass of details.

Meaning not intrinsic to sensation. It must be noted here that the sensory experience, as a component part of a perception, is itself meaningless. Meaning is not intrinsic to sensation, to image, or to affection as such. For example, if a tone were to appear alone, unassociated with any other process, it would be the sound only; it would not even be named. Unless there are associated touch experiences, it is likely that the child's first visual experience is gray only; it does not experience a blanket or any other object. Moreover, new meaning may be added to a given sensory experience. A child interprets an object as a toy, then learns that it is a poisonous snake. The roar of a motor once meant an automobile, while now it means an air liner. A liquid at first means water, then hydrogen and oxygen, and finally an aggregation of atoms or electrons. Furthermore, it is a

well-known fact that the meaning of a given sensation or of a group of sensations may be lost. Who has not observed a word of Latin or Greek and found himself unable to recall the once familiar meaning? Likewise the meaning of a chemical formula, a mathematical equation, a date, a name, or technical philosophical terminology may be lost. A simple experiment which shows how meaning is lost consists of repeating aloud at frequent intervals a word until the sound becomes so predominant that the associations vanish. Numerous illustrations of the loss of meaning may be taken from abnormal psychology. For illustration, in case of alexia, a form of amnesia, the patient can see normally, but to him a once very familiar page is now as meaningless as a page of Arabic or Chinese characters would be.

Meaning may also be delayed. Again, who has not vaguely heard a sound, and then realized a moment later that a question had been asked? Who has not had the significance of a date at last rush in? Who does not remember having finally recalled the English equivalent of a Latin verb? How many of us after an examination have suddenly recalled the answer to a given question? It is, furthermore, commonplace knowledge that meaning may exceed sensory experience. As one reads a line of familiar print the eyes pause about four times, and it is moreover unlikely that one sees even one fourth of the letters in a line; yet the meaning is clear. Likewise, one may anticipate what the author or a speaker may say. It is unsafe for an author to read the proof of his own manuscript, for all too frequently his mind will supply omissions, adjust transposed letters, and overlook other errors.

To show, further, that meaning is not intrinsic to sensa-

tion, one may note that one sensory experience may have many or very few meanings. To the writer, the sound of a siren means a fire signal, the cotton mill, a boat landing, and a Shrine ceremonial. Small words, like war, man, or truth, may be rich in meaning, for numerous associations appear with the visual or auditory stimulus. On the other hand, many words, such as zer, fey, and yev, have very little meaning. Finally, it is obvious that several different sensory experiences may have the same meaning. Take, for instance, the meaning "orange." A sound, a color, odor, taste, or touch experience may have one and the same meaning. Similarly, different experiences in the same sense field or in different sense fields very frequently mean the same thing, as a dozen different words of as many different languages may specify one and the same type of object.

Through such logical examination, as well as through introspection, sensation itself is found to be meaningless. If it were possible to eliminate all context or associated experience, mind would be, as it were, only a series of different sensory experiences. Such a condition, however, is impossible, for context inevitably accrues to the sensory core. A mental process vehemently abhors isolation. A tone, therefore, by virtue of the associated context, means whistle, piano, clarinet, locomotive, or something else; a color, a taste, an odor, or a touch likewise means something. Psychologically, perception always consists of the sensory core and its accruing context. Meaning, then, is always a complex or compound mental state; and, however difficult it might be to do so, the compound can be analyzed and its components specified. Technically, an apple, a fountain pen, or a book is a combination of several psychological data.

Moreover, such perceptive judgments as heavier, longer, smaller, and brighter are compound.

Perception defined. If such complexity exists, how shall we define meaning or perception? What is the general structure of the sensory core and its associated experiences? We shall define perception as sensation plus accruing secondary sensations and secondary images which appear in association with sensation through the influence of mental



Fig. 52.—Schema Showing Context in Perception.

set. The affective process does not necessarily appear; if it does, the meaning becomes richer, in that the meaning is then either pleasant or unpleasant. Strictly speaking, the sensory experience is the nucleus or core, while the context is the meaning. A formula, $P=S+s+i+s+i+s+i \times m.s.$, may serve as an illustration of the perceptive complex.

What do the parts of the formula signify? First, P signifies the total complex, that is, the sensory core and the context. It may generally be regarded as the perception or meaning, as, for instance, the bell, the baseball, the orange juice, or the car. The S represents the sensation. It is the experience, such as may occur in any sense field, with which the meaning originates, or with which the compound is initiated. It is, for example, the visual sensation that initiates and becomes the core of the meaning "rose," or the sound which produces the perception "violin." As we have said, it may be weak or intense, and brief or long in duration. The s represents the

secondary sensations which perhaps instantly accrue to the core. In some respects the secondary sensations may be regarded as secondary in time, if not also in importance, for their appearance seems to be directly dependent upon the appearance of the sensory core. They may, however, break away from the sensory core or fall so completely into the obscure level of consciousness that meaning is obscured; or one type of secondary sensation may be supplanted by another type, thus helping to effect a change of meaning. The *m.s.* represents the mental set.

Source of secondary sensations. But what is the source of these secondary sensations? As was pointed out, the individual human being functions as a unit; he cannot be regarded, in fact, as a dichotomy of mind and body, or as a trichotomy of body, life, and mind. When, therefore, sensory experience occurs in any field, there are concomitant bodily activities in some part or parts of the body. Examples of such changes are clear and numerous. One hears a grating sound, as when a glasscutter is drawn across glass or when a piece of grit-filled crayon scratches the slate of the blackboard, and one feels the "cold chills" along one's spine. The tingling sensations along one's spine when one hears a great organ or orchestra, and those of one's "hair standing on end" when one is suddenly frightened are good examples. One has observed his tenseness of body while he listened to Paderewski or to Kreisler, and one may have noticed strains and even fatigue in the throat after having heard a public lecture. Everyone has noticed some readers' lips move as they read silently. These bodily changes may occur in different parts of the body—the skin, the throat, the eyes, the gross muscles, the respiratory tracts. the organs of digestion—

and produce various cutaneous or kinaesthetic sensations. As we shall see in our analysis of particular instances of perception, every perception embodies some sort of coincident bodily activity which produces the sensory context.

When did such associations first occur? We do not know. Some lower animals move systematically while they are within the egg shell. Many of them appear to respond meaningfully soon after birth. For instance, a newly hatched snake will strike at an object as if in defense. For the human infant, the earliest meanings are very likely carried exclusively by cutaneous and kinaesthetic sensations; perceptions in the field of taste, smell, vision, and audition appear very soon after birth. Hereditary neuromuscular predispositions may play an important part in the earliest associations. Call them what one will, some associational tendencies seem to be established and ready to function at the time of the first postnatal sensory experiences. Many other associational bonds are formed later. They may be so numerous and the total number so large and so widely distributed throughout the body that, as in the case of anger or terror, the bodily changes seem to involve almost the entire organism.

Secondary images. The secondary images, like the secondary sensations, are imaginal experiences which accrue to the sensory core and form a part of the context. Vision offers clear illustrations of images, although imagery is, as we have said, not restricted to that sense field. For instance, one hears a roar and instantly has an image of a locomotive; a clear, lucent tone is attended by visual imagery of a cardinal in one's garden; a splashing sound has an imaginal context of a pool and a frog; a series of dull thuds is attended

by images of a typewriter; the pain on one's ankle immediately has associated with it imagery of a mosquito. Visual sensory experience, on the other hand, may produce auditory imagery; while taste and smell images are less easily discovered. Such imagery may be clear or vague, abundant or scarce. With very familiar meaning it tends to become so vague as to be almost unnoticed. In learning nouns in Latin, at first one may have clear visual imagery of the object, but with increased familiarity the imagery becomes less prominent. Finally, imagery becomes so vague that the context seems to be carried largely by kinaesthesia. For example, a typist may detect an error apparently in terms of touch only; something "felt" incorrect. In many such instances the total experience is so vague and momentary that an instant later one does not remember that any sensory stimuli occurred. For instance, the highway and the various parts of the automobile which one manipulates in driving are in consciousness, but they may be so definitely in the obscure level that one may appear to drive almost automatically. Again, at first the typist writes laboriously, for every key and every movement are clear in consciousness; but, later on, when the typist has become expert, the visual stimuli seem to flow easily, swiftly, and almost automatically from, say, the eyes over nerves and muscles on out through the finger tips, so that the operation appears to be reduced largely to a condition of kinaesthesia. But some sensory basis does exist, however obscure it may be.

Changes of meaning. Everyone is familiar with the fact of changes of meaning. One sensory experience may have, in sequence, several meanings. How do such variations occur? Technically, they are reducible to changes in the

sensory and imaginal context. When the visual stimulus means a package of matches, one group of secondary sensations and secondary images accrues to the visual core; when it means lipstick, another different context occurs. A high tone may at first mean mouse and then Galton whistle, because of the change of the context. Many ambiguous figures, as the duck-rabbit figure, are based upon a shift of the context. As we have said, the context is the meaning, and when a different context appears the meaning changes.

Mental set. Mental set is the condition or the mental attitude of the individual at a given time, which tends to cause a given type of context to accrue to the sensory core. In other words, under one condition, one type of sensory and imaginal context will occur, while under another condition one is "set" or disposed so that another different type of context will appear. But what is this "set" or disposition? It may be analyzed into at least four intimately related characteristics.

First, there are nervous predispositions. It is believed that, in the case of often-repeated experiences, such modifications of the nervous system may occur as to make the associations habitual. Consequently, the sensory stimulus provokes not only the sensory core of experience, but it also easily spreads to such efferent nervous tracts as were formerly involved. Second, muscular adjustments may occur. The body may, as it were, become modified within limits so that response occurs more readily. The analogy is somewhat misleading, but let us say that the training of the body is somewhat like the readjustment of a new hat or a new suit until it fits better with age.

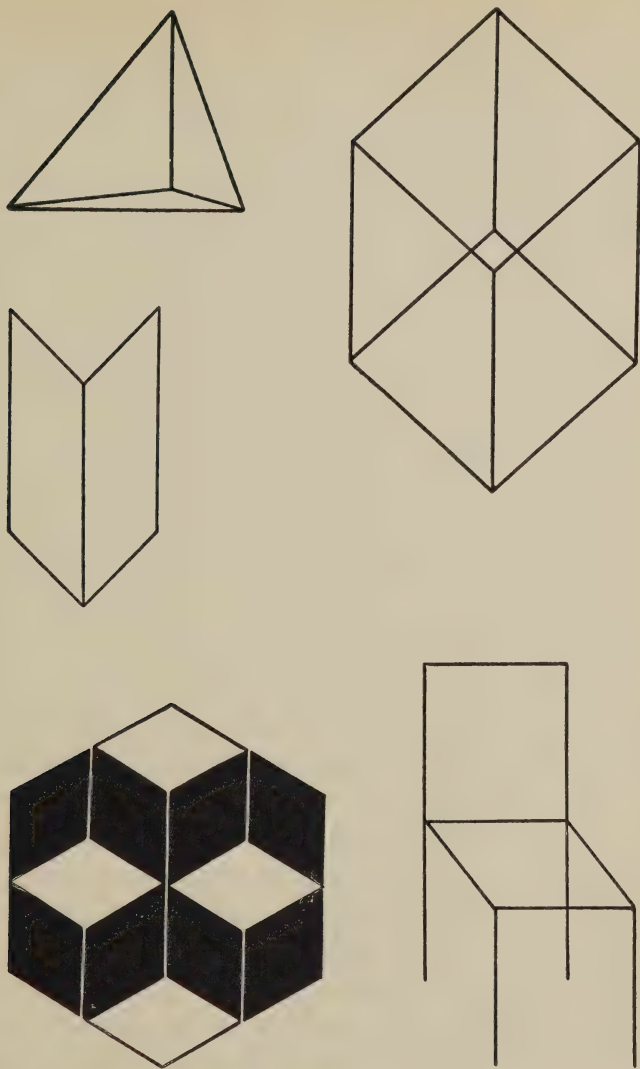


Fig. 53.—Ambiguous Figures. (Fixate constantly a point near the center of a figure until the figure changes.)

Third, psychological associations are formed when a given type of sensory experience is had, so that, when that type of sensory experience is repeated, the same type of associations tends to occur. A peculiar series of tones, for example, was associated with a brown thrush in a rose arbor; and now, when the sounds are again heard, visual imagery of a brown thrush in the rose arbor appears. Another type of tones became associated with a grand piano; and visual imagery of the piano appears when such tones are now heard. Likewise, a touch experience habitually produces images of a pen, an odor regularly provokes imagery of a rose garden, a taste usually arouses imagery of an orange, and so on.

Fourth, the physical environment in which one finds himself at a given time attunes, as it were, the individual to make certain associations rather than others. In this relation anyone knows the general influence of one's environment upon his mental attitude, whether he is conversant with the technical facts involved or not. The differences in attitude produced by a formal dinner, a church, a classroom, and a ball game are obvious. It should be specified that not only the type of a building or the occasion, but also such matters as the color of the walls, the lighting, the temperature, and the ventilation of a room play a part in the formation of one's attitude at a given time, for one is constantly bombarded by such physical stimuli.

In another section we saw something of the sensitivity of the human sensory mechanism, and it needs to be noted here that the general mental disposition of the individual at a given time is in no small measure produced by these stimuli. It is not strange, therefore, that a given tone means a tuning fork when heard in the lecture room, and a piano when

heard in a home. The environment has thus aided subtly in adjusting the individual to make such associations. It goes far toward offering an explanation why different meanings, once established, appear under different circumstances. Now, as we have said, it appears that an individual human being is a unit; therefore, since the four characteristics of mental set, which for the sake of clearness were listed separately, are established functionally together, it is easily understood why a given context, composed of certain types of secondary sensations and images, tends to appear under certain circumstances. The law of association simply tends to produce certain previously established associations.

The place of affection in perception. Affection, although not indispensable to perception, must not be disregarded here. When the affective process appears, the meaning becomes richer by virtue of the fact that the affective process makes the total experience either a pleasant or an unpleasant one. The appearance of the affective process and the quality usually associated with a given sensory core is, as a rule, determined by the law of association. It is no more a matter of chance that the perception "rose" is pleasant than it is that the sensory experience comes to mean "rose."

With the formula or principle of perception before us, it should be reasonably easy to understand the nature of particular meanings. We may be certain that the principle of perception holds true in every perceptive or meaningful experience, whether or not we know all the facts about a given perception. The great difficulty with the analysis of perceptions arises from the wide variety of experiences of one individual and also from vast differences in the training of different individuals. Such a vast number of contexts of

a given type of meaning is possible, that one can rarely be sure that he has a complete list of the data composing the context of one of his own perceptions at a given moment; to know the data that actually compose a meaning in the mind of another person is obviously much more difficult.

The illustrations that appear in the following chapters are, nevertheless, somewhat typical. They show, at least in principle, how data form the context of a meaning, although one cannot safely assert that a given perception embodies all of the data specified, or that the perception is restricted to those data. For example, one mind may have had few or many experiences associated with a given type of sensory experience; also, if we assume that the sensory experiences of different people are approximately alike in kind and number, the associations formed through combinations of the mental data will vary widely with these different people. Minds behave generally in the same way, but the thoughts of no two people are precisely alike. To employ familiar language, the environment and training of different individuals differ so much that it is here almost impossible to do more than name the primary sensory stimulus and then specify some typical secondary sensations and secondary images. It is to be understood, then, that the principle of perception applies in every case, and that types of data may vary with different minds. In our study only simple perceptions will be taken from the different sense fields.

Let us turn to the illustrations.

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CHAPTER XII

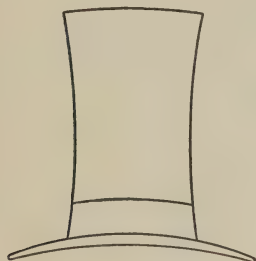
Perception: Visual

THE field of vision is a familiar and convenient one. It appears to lend itself to us for investigation more readily than do some other sense fields. But before we can proceed with illustrations of perception, it must be remembered that visual sensory experience as such does not intrinsically include the world of objects as one perceives them. It is necessary for us to be clear here, even if we become accused of apparently unnecessary repetition. If the sensory experience appeared alone, vision would consist of a series of colors and grays only. There would be no such meanings as squares, triangles, trees, or cars. All such things in reality are complex mental states. Visual space, except in the sense of the attribute of extension or "spread outness" which is characteristic of pure sensation, would not exist. Now suppose visual experience were stripped of all context, that is, of all lines, all shadows, and all other secondary cues; under such a condition the observer would at the moment experience only sensory qualities having also the attributes of intensity, extensity, protensity, and attensity. The experience would, for example, be white, and not white paper; red, and not red rose; black, and not a fountain pen.

Moreover, pure visual experience is, in the usual sense, neither bidimensional nor tridimensional. In a technical

sense, one does not see the top of the table as flat nor a baseball as round; such dimensions are perceptive. Stripped of all cues or associated processes, a visual sensation is "pre-dimensional," that is, a spatial condition having the nature of, so to say, an intermediate between bidimensionality and tridimensionality. For instance, if one looks monocularly through a small opening into a hollow sphere where there is uniform illumination, and where there are no lines, shadows,

or other cues to distance, the experience will be "predimensional"; it will be spatial, but it does not have flatness or volume in the usual sense. Such dimensions, as we have said, occur upon the appearance of associated experiences or context.



After Luckiesh

Fig. 54.—An Illusion of Height.

Bidimensional space. The Müller-Lyer illusion offers a convenient illustration for the study of the perception of bidimensional visual space.

In this illusion, as we have seen (page 20), segment *A* seems shorter than segment *B*, whereas physically the two segments are the same length. Obviously the difference between the physical length and the psychological length is to be found in perception. The difference is caused by mental processes associated with the visual sensory experience black and white. Let us, then, keep our formula of perception before us and undertake to discover the constituent parts of the total experience.

As stated above, it is unlikely that one may list all the different experiences in a given perception, but, in general, the following increments occur. First, the primary sensory

experience is black and white. These two visual qualities, as the sensory substance of this perception, initiate or touch off the experience, thereby causing the rise of accruing parts of the experience. Next, secondary sensations are produced by movements of the eyes. In a previous section we noted that the eyeballs are moved by three pairs of muscles, the external and internal recti, the superior and inferior recti,

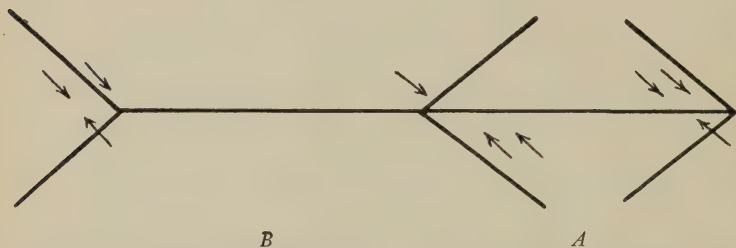


Fig. 55.—The Müller-Lyer Illusion. (The arrows indicate the direction of movement of the eyes and the points at which pauses occurred.)

and the superior and inferior oblique. The reciprocal contraction and relaxation of these muscles, with the consequent movements of the eyeballs in their membranous sockets, produce sensory experiences of strain and pressure, experiences which are readily noticed if one turns the eyes far toward the left or the right or in any other direction. Photographic records made while one fixated a small Müller-Lyer figure, placed horizontally, show eye movements. In the illustration the small pointers show the direction of the eye movements associated with the observation of the two connecting segments of the illusion. These strains, let us remember, accrue to the primary sensory experience so quickly that the time interval that may be necessary for them to appear cannot normally be detected.

Third, empathy provides a source of secondary sensations

consisting primarily of pressures and strains. Empathy is the psychological projection of oneself into the place of some observed object or individual and is thus oneself experiencing what that object or individual appears to experience under the circumstances. For example, observe a statue of Atlas supporting the world on his shoulders; columns too



Fig. 56.—Figures Which Arouse Empathy.

small in diameter for their height and the weight they support; the Laocoön group; amateur toe dancers, and the like, and note the strains in your muscles and limbs. If one goes into a room where the ceiling is very low, the pressures and strains on the scalp and shoulders are very pronounced, while, if one enters a room which is spacious, a feeling of light pressure, sometimes characterized as airiness or bright pressure, occurs. It is such sensory experiences that one mildly experiences with the Müller-Lyer illusion, for while observing the figure, one tends to place oneself within the relatively restricted area of section *A* and then in the relatively large area of section *B*, and thus experiences conditions

of empathy as though restricted in the first area and unrestricted in the second.

Fourth, imagery appears from the tendency of the observer to consider the half of the figure, in general designated by *A*, as a unit, and then that designated by *B* also as a unit. The imagery is somewhat like memory overlay or tied imagery. In this way section *A*, taken as a unit, becomes about one fourth as large as section *B*.

Now what occurs with reference to the various experiences—the colors, the strains and pressures, and the images—involved in the illusion? The mind instantly combines all these different experiences; the experiences in combination are the meaning “longer than” or “shorter than.” If the affective process enters into the complex, the meaning is thereby made a pleasant or an unpleasant one, accordingly as the quality of that process is pleasantness or unpleasantness. It should be stated here that the compound is not constructed anew each time, for, as specified earlier in the discussion of perception, the mind can retain the compound itself as a unit and may need only the sensory stimulus to touch off the experience.

Tridimensionality. The visual perception of tridimensionality embraces, as does bidimensionality, many different types of experience. Of course one may perceive volume through other sense fields. Touch is one of the best means for the development of the meaning of volume, for with the flexible limbs, the pliable skin, and the various changes of position of the skin, the limbs, and the posture of the body, even the blind may form clear perceptions of volume. It is very doubtful, however, that the visual perception of a flat or a voluminous object would ever be so pronounced as

it is were it not for the influence of touch. But what experiences may become associated in the formation of the visual perception of volume?

First, there is the primary sensory experience. The quality and the other attributes of the primary sensory experience depend, in general, upon the object in question. In quality a baseball is gray and black; a book is blue; an apple is red; a landscape includes greens, browns, grays, and whites. But, irrespective of the qualities, there would be no visual tridimensionality without accruing secondary sensations and images. The primary sensory experience merely serves as a core to which the context accrues; it touches off or starts, as it were, the development of the total complex.

Second, eye movements arise from secondary sensations. When one observes a book, a desk, or any other such familiar object, the eyes usually move horizontally, perpendicularly, and obliquely over the object, thus bringing into play each pair of muscles. Strains and pressures, usually very mild, are set up by such muscular movements, just as such experiences were aroused in the perception of bidimensionality. Here, however, the range of movements may be much wider than in the case of a small Müller-Lyer illusion.

Third, strains arise from convergence of the eyes. In normal binocular vision, the eyes become more converged as an object of vision is brought nearer the eyes. Fixate, for example, the end of a pencil held at arm's length from the eyes; then bring the pencil slowly toward the bridge of the nose. Note the strain in the region of the eyes, and observe how this strain increases in intensity as the pencil is brought nearer the eyes and as convergence increases. Normally, strain from convergence is operative within approxi-

mately sixty-five feet; beyond that distance the eyes become so nearly parallel that the experience of strain does not occur, although physical convergence exists for a much greater distance than sixty-five feet.

Fourth, strain arises from accommodation. In our examination of the structure of the eye we discovered that the

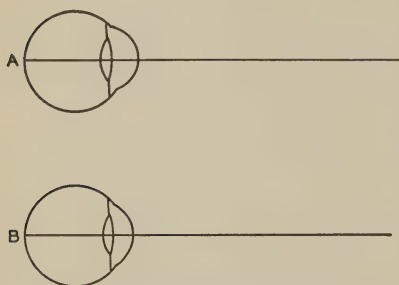


Fig. 57.—Diagram Showing Parallel Lines of Sight. (No strain from convergence occurs under such conditions.)

crystalline lens is adjusted reflexly by the ciliary muscles for far and near vision. Within limits, the lens becomes thicker for near vision and thinner for far vision. Faint experiences of strain have been reported when the object of vision is moved back and forth within a

distance of about six and one-half feet from the eye.

A brief report of an experiment will show how perception is affected by accommodation. A large box is so constructed and so uniformly illuminated inside that the observer can discover no lines, shadows, or any other cues by which he can judge distance from him. Suspended across the interior is a narrow strip of metal which, from the exterior of the box, can be moved known distances to or from the observer, and so arranged that the size of the retinal image is kept constant. The effects of binocular vision are eliminated by having the observer use only one eye in making his observations; he looks at the stimulus through a small opening so devised that eye movements and shifting retinal images are avoided. The only ocular changes are those

associated with accommodation. Under such conditions, with all cues except those of accommodation removed, the observer could judge with some measure of accuracy differences in the distance of the physical stimulus from him. From such experimental work it is inferred that, as different parts of an object and the farther and nearer parts of a book are fixated and as accommodation occurs, slight sensations of strain arise and form increments of the perceptive complex.

Fifth, there are retinal images. One is seldom clearly aware of the existence, the nature, and the effects of retinal images. One usually thinks of them only in terms of mere patterns formed by light waves on the retina where, through chemical modifications, nervous impulses are initiated. The variation of form and the localization of retinal images, both in monocular and in binocular vision, play a significant rôle in the visual perception of tridimensionality. In order to get the problem before us, we need to consider, first, the nature of identical and disparate retinal images. In monocular vision, identical images are defined as two or more images which occur simultaneously on one part of the retina. These images may cover the same area, they may overlap only in part, or they may occur so near each other that no unstimulated area of the retina may exist between them. Disparate images, on the other hand, occur when the images appear on different sections of the retina, there being at least a small unstimulated area of rods or cones, or both, between the images. In binocular vision, identical images are those which appear simultaneously on corresponding parts of each retina. For illustration, if one placed one retina over the other and stuck a pin through them, the

pinhole would represent identical points which appear at the same relative positions on the retinas. Disparate images are those which appear at relatively different places on the

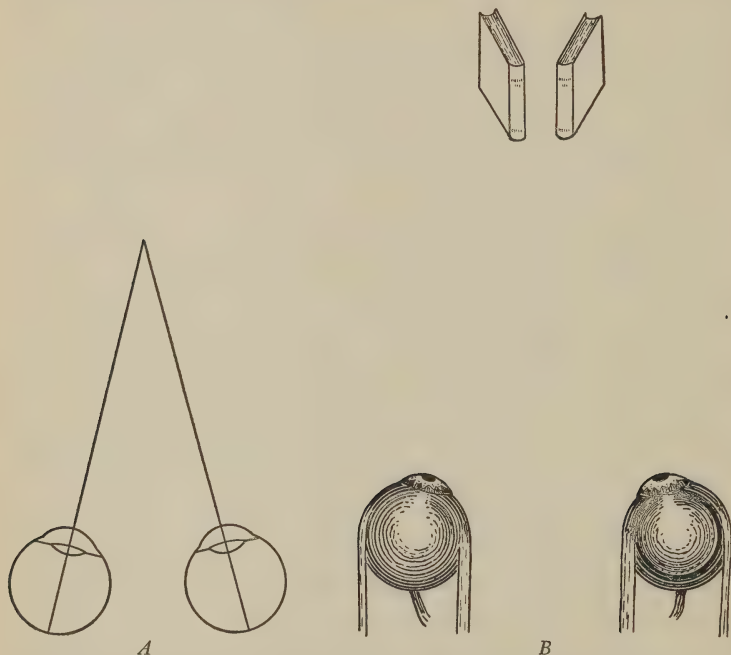


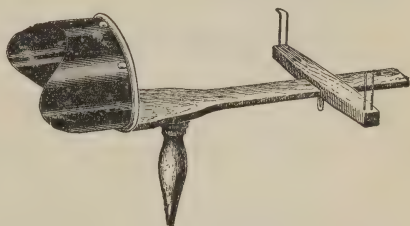
Fig. 58.—Diagrams Showing Convergence in Binocular Vision. (*A*, simple convergence; *B*, convergence and double images.)

retinas. What are the psychological effects of such differences in retinal images?

Suppose one places a book about 15 inches in front of the eyes, and then fixates the back of the book first with the right eye and then with the left. Obviously there are two images having a section in common: with the right eye one has an image of the back, the top and the right side of the book, while with the left eye one has an image of the back,

the top and the left side of the book. With binocular vision, a filmy visual condition appears, and the mind imperceptibly snaps the two images together, thus giving the appearance of solidity or tridimensionality to the experience. Again, hold a pencil about 12 inches from the eyes, fixating it with first one eye, then with the other, and then with both. Clearly, there are two images which are fused psychologically when binocular vision is employed. Then hold two pencils so that one is 8 inches and the other 15 inches away. Fixate one and then the other.

When one pencil is fixated binocularly, the other appears as two because of the pronounced existing retinal disparity. Still again, the effect of binocular vision on the perception of distance may be tested easily. Let one place a curtain ring, 2 inches in diameter, edgewise 24 inches before him, close one eye, and then with a sweeping movement of the flexed right arm, say from right to left, undertake to put his finger or a pointer through the ring. Under such conditions one usually misjudges this distance from one to three inches, whereas no appreciable error is made when binocular vision is employed.



C. H. Stoelting Co.

Fig. 59.—Brewster's Stereoscope.

The stereoscope also affords a convenient means of studying the effects of binocular vision. The Brewster's stereoscope is designed to give perception of depth, or distance from the observer. It controls, therefore, two important factors, namely convergence and retinal images. The parti-

tion at the front of the hood prevents convergence by causing the lines of vision of the eyes to become more or less parallel as is the case when one fixates a distant object.

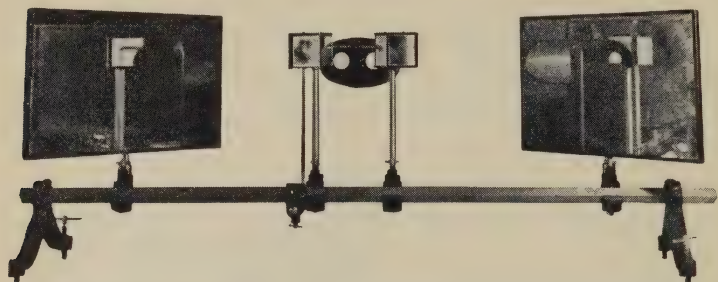


Fig. 60.—Titchener's Stereoscope, Telestereoscope, and Pseudoscope.

Then, too, the two stereoscopic images are in part unlike each other; in some measure they resemble the disparate images which would normally appear when one fixates an object.

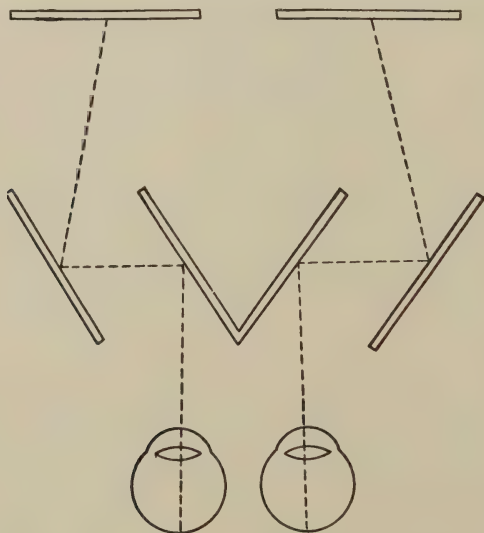


Fig. 61.—Diagram of Stereoscopic Vision.

The stereoscopic slides are two photographs made from different points of view by means of a stereoscopic camera which has two lenses set approximately six inches apart. When, therefore, one uses the stereoscope, he not only has the sensory stimulus but he also experiences cues similar to those appearing in normal vision when a distant object is fixated; consequently the perception of distance and volume is had. The telestereoscope is an instrument devised to prevent convergence and to exaggerate the disparity of the retinal images. An arrangement of mirrors causes the lines of vision to be parallel and, at the same time produces two points of view such as one would have if the eyes were, say, 18 inches apart. With, then, the increase in retinal disparity there occurs an increase or exaggeration of the perception of the third dimension.

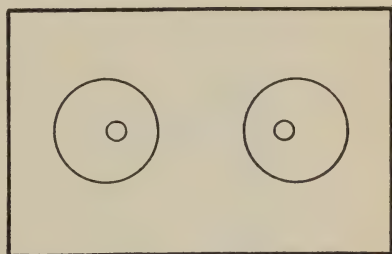


Fig. 62.—A Stereogram. (If one holds the book about 12 inches from the eyes and then fixates a point as if it were 12 inches behind the stereogram, the two circles will become joined and give the perception of tridimensionality.)

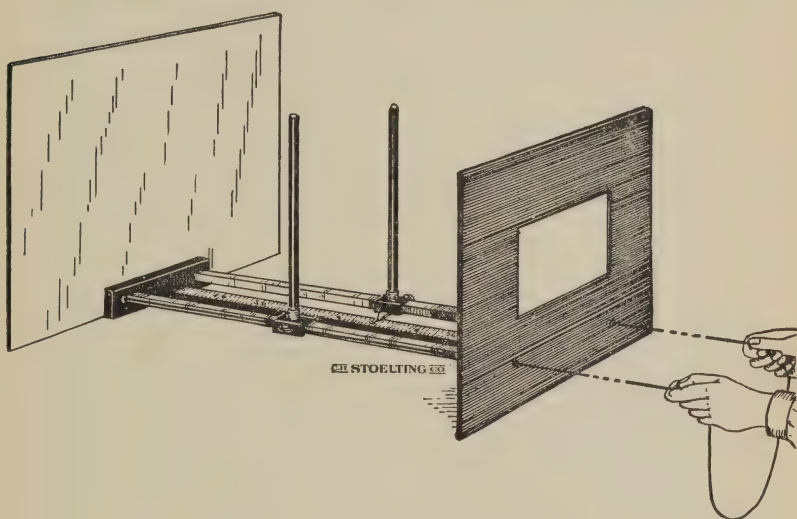
The pseudoscope also serves to show the effects of binocular vision, especially with respect to retinal images. Suppose one's eyes were suddenly shifted so that the observer would see as from the left side with the right eye and from the right side with the left eye. This is precisely what the pseudoscope does. Through an arrangement of mirrors, the right eye observes the left side of an object, while the left eye observes the right side of the object. The cues are thus re-

versed. Under such conditions the mind continues to judge or perceive in terms of old cues, and now when the cues are reversed the perception is reversed. For instance, if one uses a pseudoscope to observe the inside of a cup, the inside of the cup is seen as convex. In this way a bas-relief becomes an etching, and a mask is seen as concave instead of convex. In general, the normal condition is reversed, the nearer parts are perceived as more distant while those farther away are perceived as nearer. As we shall see in a later section, the mind makes its associations in an orderly, lawful manner. It establishes, as it were, modes of association which tend to persist, and thus the same perceptions tend to occur in connection with a given stimulus when the secondary sensations and images accrue. When, therefore, the pseudoscope reverses the position of the images, the mind interprets according to its previously established modes of association; hence the meaning is reversed.

Habitual cues. In addition to such secondary sensations and secondary images as have been specified, there are numerous habitual cues which one constantly employs in visual perceptions. They are called habitual cues because one habitually uses some, if not all, of them in judging distance from one, and also in the perception of volume. From infancy one learns to judge in terms of these factors, and thus their influence is as certain as it is usually unnoticed. Illustrations will indicate the nature and influence of these cues.

Aerial perspective. If one lives for a long time on the coast where the atmosphere is relatively foggy, one will judge the distance away of a house or a mountain in terms of those conditions; a relatively clear object is thought to be near, whereas a hazy or obscure object is believed to be farther

away. In this relation every one has noticed how much nearer the stars seem to be on a very clear evening and then how much farther away they are on a hazy evening. Let one go from the hazy coastal region to a section of the country where the atmosphere is rare and very clear; he will,



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Fig. 63.—Howard and Dohleman's Depth Perception Apparatus.

habitually, continue to judge distances in terms of old conditions, and consequently he will make numerous gross errors in his estimates of distance. A distant lake consequently seems near by; the opposite wall of the Grand Canyon appears to be the distance of a stone's throw, when in reality it is a thousand feet away; a town is judged to be a mile away when in fact it is two miles distant. Such errors are to be expected when habits of mind have been established under different aerial conditions. This is one of the factors which

make possible the control of the effects of distance in stage scenery, for on the stage the intensity of the lighting may be increased or decreased to give the perception of greater or less distance.

Relative size. In the case of familiar objects, other things being equal, one perceives the large as near and the small of

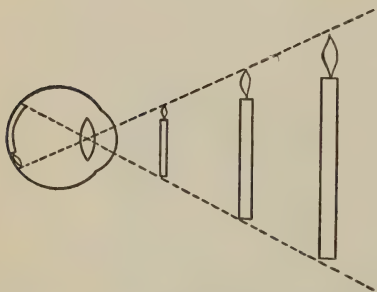


Fig. 64.—The Relative Size of the Retinal Image. (If a familiar object, as a candle, or a dime, is moved away from the eye, the size of the retinal image decreases according to the square of the difference in the distance. Perspectively, however, there may be little change in the size of the object.)

the same type as far. Examples of the influence of relative size are numerous. An airplane is thought to be not very high if it is seen as large; it is thought to be very high when seen as very small. The perception of distance will change if one discovers that the plane is a large transport instead of the small cabin plane, as he first thought. If the retinal image of an eagle is small, the bird is be-

lieved to be far away; if the image is relatively large, it is believed to be near. In moving pictures, illusions of distance are commonplace, for such illusions are easily produced by the use of context, that is, by establishing a comparison of them with other familiar objects in the field of vision. In the case, however, of many objects of known standard size, the decrease in their size as perceived does not vary constantly with the decrease in the size of the images. If, for example, a man approximately six feet tall walks away from one, his size remains somewhat constant because of one's

familiarity with the normal-sized man; the mind habitually tends to keep him at somewhat the normal stature even though the retinal image becomes increasingly smaller. A dime, likewise familiar with respect to its size, remains perceptively larger than would an unfamiliar object of identical size when it is moved away the same distance. This appar-

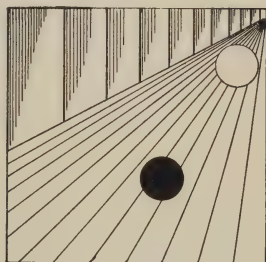
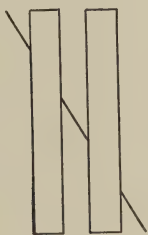
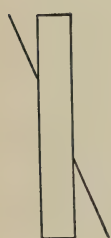
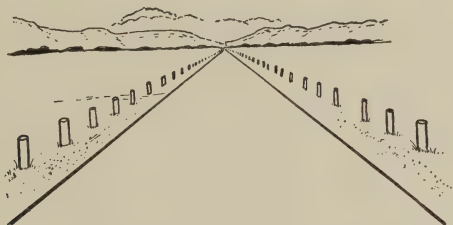


Fig. 65.—Linear Perspective.

ent violation of the rule is in fact no variation from the principle of the lawful behavior of mind in perception, in that no one secondary factor may generally control meaning.

Linear perspective. This influence enters into a large percentage of our visual perceptions. Almost all sketches, photographs, landscapes, and visual objects in general consist of an arrangement of lines. A book, a desk, a fence, a line of telegraph poles and wires, a tree, a house, and a road are characterized by numerous lines leading in different di-

rections in that area of the field of vision. These lines of colors and grays, variously distributed, exist in their own right and also serve to bring about the appearance of tied images and memory overlay. Examine a sketch showing the framework of a box. Physically, the lines forming the framework are obviously in two dimensions, but perceptively they are in three dimensions, and it will be noticed that five of the planes are distinctly filled in with a vague, filmy substance. Now examine the objects in the room—the desk, the bookcase, the reading lamp, the typewriter, the rug, a chair—and you will readily discover the significant part lines play in the formation of judgments of volume or distance away. If all linear effects were removed from the field of vision, it would be a peculiar and strange world indeed.

Interposition. Again, examine a linear sketch of a box, a table, a chair, or some other familiar object. It will be discovered that some lines obscure other lines, and that those which represent the nearer portion of the object obscure in part those indicating the farther sections. An examination of the objects within a room, the trees and the buildings on the campus, and the mountains in the distance will reveal that the more distant objects are partly hidden by the nearer. They have been seen in this way throughout one's lifetime, and thus one has come to judge the relative distance of objects in terms of interposition; and since such judgments have occurred so frequently, they now occur in this way incredibly quickly and easily.

Superposition. Once more, examine an artist's reproduction of a landscape. In general, the objects in the foreground are not only more fully outlined and less hazy than others, but they are also placed near the bottom of the can-

vas. Note, for example, the location on the canvas of a stream or a road leading away in the distance; usually it is placed higher as it becomes more distant. The artist is merely undertaking to reproduce an area of the field of vision as one normally sees it. The horopter shows that objects in the field of vision are normally distributed as the artist represents them. The horopter is a map of the lines of the field of vision at a given moment. What normally are the lines of vision? What is in a very general way embraced within the range of vision as one moves about in daily routine? In what direction are the eyes usually turned? An illustration will suggest the answers. As one walks along the street, on the campus, or by the seashore, it is likely that one's eyes are turned toward the ground only a few yards ahead. The nearer objects are thus in the lower half of the field of vision, while the more distant objects are in the upper half. It is, therefore, only natural that one judges distance in terms of superposition.

Light and shade. The world of vision is composed qualitatively of colors and grays. The distribution of different shades of gray, or of light and shade, plays a significant part in visual perspective. A photograph is an arrangement of light and shade; a view of the campus shows an innumerable number of illuminated and shaded areas. If the normal distribution of light and shade were reversed, the perception of volume or distance would be greatly modified, if not largely reversed. Invert a photograph of an irregular surface which has a pronounced distribution of high lights and shadows and you will discover that the projections become indentations and that the indentations become projections. Why does such a reversal of meaning occur? It is because the mind

persists in its tendency to interpret the visual field according to the method it normally follows. What is the normal distribution of light and shade? The light usually falls upon an object from above, as sunlight upon a tree; the shadows are generally on the lower part of any projections, and on the upper part of indentations. One thus observes and

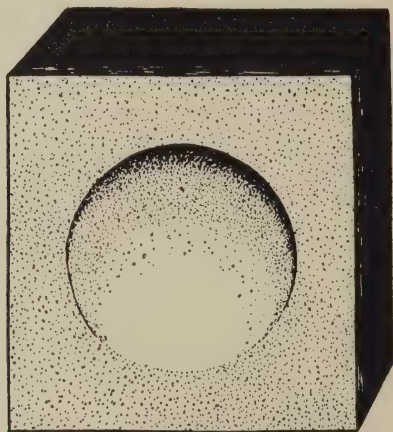


Fig. 66.—The Influence of Light and Shade.

judges in terms of the position of the areas of light and shade. Modify this normal arrangement, and the perception of the object changes. Architects, sculptors, and curators of art galleries have for many centuries been aware of this influence. Buildings are designed to give optimum effects of light and shade; statues and paintings vary greatly in appearance as the intensity and the distribution of lighting are changed; the contour of a cliff may become modified by the shadows and the high lights which change as the sun passes from east to west. Briefly, the world would not look like the same place if all effects of light and shade were eliminated.

Uniformity. The visual field of most people is broken and irregular. One sees hills, mountains, valleys, and ravines; there are terraces, trees, shrubs, and houses; or perhaps the view consists of streets, sidewalks, transmission lines, automobiles, and skyscrapers. Suppose one goes from



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Fig. 67.—The Influence of Light and Shade. (Turn the bottom of the picture up and observe the change of perspective.)

such conditions where he has habitually learned to estimate distances in terms of such irregularity of the field of vision to a place where the view is uninterrupted by such objects. Let him there estimate the number of miles it is across a lake, the length of a bridge extending across a sound, or the distance he is from a town as seen across a plain. He will form his estimates under the influence of the habit of mind

established under other conditions; consequently his errors will be large. Three miles will probably seem to be not more than one; and he will have difficulty in convincing himself that he is in error.

The visual perception of movement. In an effort to list the typical processes that enter into the perception of movement, one must remember again that wide divergence from any fixed list may occur in case of different individuals and with the same individual under different circumstances. Each type of perceptive experience must be investigated if one is to have exact analysis, somewhat as the medical diagnostician fully investigates complications because they may be associated with some type of organic disturbance. In general, then, the analysis here offered is more representative than it is exact.

The nature of the primary sensory experience which arouses the perception, of course, depends, in a given instance, upon the physical stimulus and its environment. The sensory stimulus may be the red of the cardinal flying by the laurel, the green of the navigation lights of an air liner against a background of gray or a field of stars, or the blue of a car on the black pavement. Obviously, the sensory field may be very complex. What factors may be involved in the perception of movement in the field of vision?

Afterimages. When relatively intense stimuli are used, positive afterimages play a significant rôle in the perception of movement. It will be remembered that the retina seems to function chemically and that its activity continues for some time after the removal of the physical stimulus. Suppose we note here some effects of moving stimuli. If, in a dark room, an electric light is moved very swiftly in a circle,

say, two feet in diameter, the observer will see a stationary visual object, that is, a stationary circle of light. Reduce the speed of movement of the bulb, and the perception of movement in a given direction will occur. The perception of the direction of movement of light, whether clockwise or counterclockwise, is effected in part by the fact that at a given moment the most intense area, that is, the head of the comet-like experience, corresponds to the position of the physical stimulus, while the sensory experience becomes relatively fainter until it is least intense at the other end. One has learned to judge the direction of movement of such objects in terms of the relative intensity of the different areas of the sensory experience; if the more intense part is at one's right, then the object is perceived as moving toward one's right. Again, for example, if the light bulb is moved swiftly from left to right across the field of vision, the comet-like afterimage trail occurs; consequently the perception of movement from left to right is had. The direction of movement here likewise corresponds to the direction of the relatively greatest intensity. Illustrations of this influence may be seen in the blurred lines used in an artist's representation of a car, a train, an airplane, or some other swiftly moving object; such lines suggest both their swift movement and the direction of their movement because the lines somewhat correspond to conditions which normally occur in the visual fixation of rapidly moving objects.



Fig. 68.—An Illusion of Visual Movement.

Nystagmus. One's eyes usually tend to follow a physical stimulus which moves across the field of vision. This movement of the eyes consists of a succession of swift jumps or shifts rather than a continuously uniform motion. This nystagmus or jerking action of the eyes involves one or more pairs of the external muscles of the eyes, and from such activity arise secondary sensations. One may easily discover

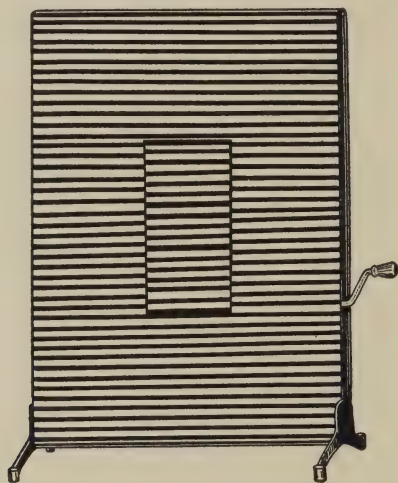


Fig. 69.—James' Waterfall.

the effects of eye movement. Fixate a point at the center of the movable section of James' waterfall; as that section moves downward the eyes tend to follow the lines but jerk back to the central part which the observer undertakes to fixate constantly. The central area of the waterfall is perceived not only as moving downward, but the sides appear to creep upward, just as they do when one looks at a large waterfall bordered by narrow cliffs. When the movable part of the

apparatus stops, that section seems to creep upward, an effect produced in part by eye movement. The spiral disk is also frequently employed to demonstrate the influence of eye movement. If the disk is turned slowly in one direction, it seems to shrink in size; if it is turned in the other direc-



Fig. 70.—Spiral Disk. (If the disk is rotated slowly in one direction, the disk will appear to decrease in diameter; if it is rotated in the other direction, it will seem to increase in diameter.)

tion, it appears to become larger in diameter. Moreover, it appears that such effects can be had without the use of a moving physical stimulus. If, in a dark room, one fixates a small stationary pinhole of light at a distance of about five feet, the point of light may appear to move as much as one foot. The sensations arising from eye movements appear to be sufficient to touch off the so-called illusion of movement, although some psychologists believe that the illusion is caused by other factors.

Imagery. The impression must not be had that secondary sensations alone provide the accruing processes necessary to the visual perception of movement. Visual memory images also occur, especially in observations where the physical stimulus moves too slowly to produce sensory afterimages. For instance, one does not see the minute hand of his watch move, yet he knows that it has advanced ten minutes; this

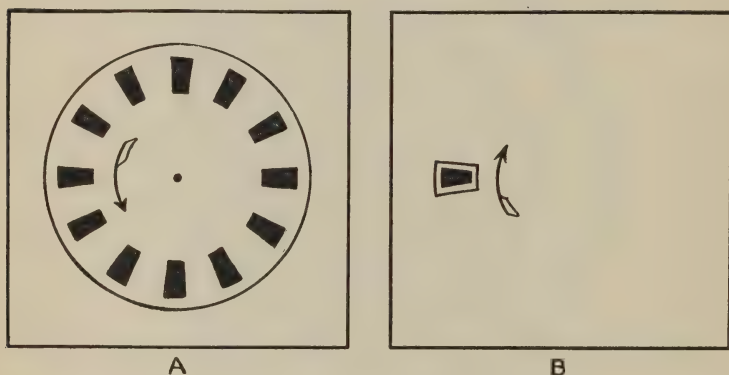


Fig. 71.—Bourdon's Apparatus for Showing Illusion of Movement. (When the large disk, *A*, is placed behind the screen, *B*, and rotated slowly so that the black rectangles pass downward behind the window one perceives the black rectangle as moving upward.)

perception is possible because of a memory image of the hand at the former position on the dial. The mind is able thus to compare, as it were, the present sensory experience with the former. In case of slow but unobservable movement, one constantly refers the position of the stimulus at a given moment to the position it occupied at some previous moment. For instance, one's observation of the movement of a car along a highway, of a baseball across the diamond, and of a robin across the lawn involves references made pos-

sible through imagery, and the perception occurs easily. Movement across a uniform background, as that of a watch hand on a dial of plain white paper, is not so easily or accurately perceived, for here landmarks are rare.

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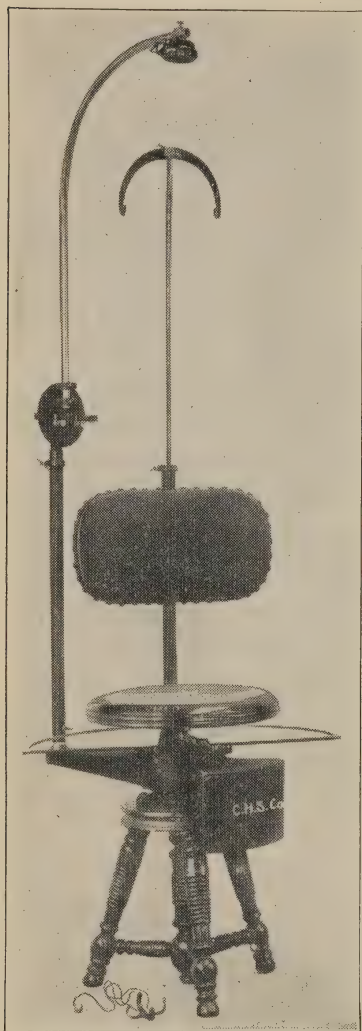
CHAPTER XIII

Perception: Auditory and Tactual

IN THE field of auditory perception it becomes necessary to distinguish between, say, a pure tone and the perceptions involving the localization, the distance away, the direction of movement, and the physical source of the experience. One hears tones and noises; one perceives the sound of bells, automobiles, trains, birds, radios, radiators, pianos, rifle fire. One hears a tone; it is perceived as located approximately five yards to one's right, or as moving from right to left, or as moving from left to right, or nearer or farther away. The sensory experience, if it appeared alone, would consist of tones, noises, or a combination of the two, having the attributes listed in our discussion of auditory sensation. The sound itself is not intrinsically distant or directional. Our problem, then, consists of discovering the typical accruing sensations and images which, becoming associated with the sensory experience, constitute the meaning of direction, or distance, or movement.

. **The perception of direction.** In binaural audition, the perception of direction of the source of the sound is difficult unless the intensity of the sensory experience is greater with respect to one ear than it is with the other. For instance, assuming that the ears are of equal sensitivity, the source of the sound is located at one's right if the sensory experience is

more intense in the right ear than in the left; it is located at one's left if the intensity is greater in the left ear than in the



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Fig. 72.—Sound Cage.

right. Let us specify two means that one may employ to test this perceptive effect produced by variations of intensity. Let the observer, who is blindfolded, sit in a sound cage. The physical stimulus is located in the sound transmitter on the extension arm which may be turned so as to assume any desired position with reference to the observer's head. Now, place the arm holding the stimulus box so that the sound will occur equidistant from the ears; the sound waves reach the ears simultaneously with equal intensity. Under such conditions, when the stimulus is a faint noise or a weak simple tone, the average error in localization is relatively large. Move the arm 45 degrees to the right; the sound waves will not strike the ears simultaneously, owing to differences in distance and the interfer-

ence of the intervening parts of the head. Under these conditions the average error in the perception of direction is comparatively small. The experiment may be continued by placing the sound box directly in front or directly behind the observer's head, or at any angle to the right or left. It will be found that, when other cues are eliminated, median stimuli generally produce relatively large errors, while lat-



Fig. 73.—Young's Pseudophone.

eral stimuli enable one to judge direction relatively accurately.

The effect of intensity may be examined further by means of a pseudophone. This apparatus consists of two ear trumpets which cross each other above the head so that the sound waves from one's right side are transmitted by the tube to the left ear, while those from the left side are carried to the right ear. The directional cues are thus reversed. Here again, when all other cues to direction are eliminated, the perception of direction is likewise changed so that the sounds from the right appear to be located at one's left, while those on the left appear to be on one's right. In such experiments

intensity is the one constantly variable factor; one may assume, therefore, that, in binaural audition, the difference in intensity as associated with the two ears gives definitely a cue to direction. One would guess that such influence occurs irrespective of the use of the sound cage or the pseudophone, for one has noticed that he himself, as well as other people and lower animals, frequently turns his head in an effort to locate the source of some faint sound. Moreover, echoes, as those coming from the side of a building, frequently give one an incorrect perception of the direction of a passing locomotive or an airplane. In such instances the error of direction is caused by the fact that the most intense sound waves are deflected from the side of the building to one's ears, and so one habitually localizes the source of the sound as in that direction.

Bodily movements. Involuntary movements of one's head or other parts of the body frequently occur in response to auditory stimuli. From such movements secondary sensations arise which add to the total perceptive complex.

Visual images. Visual images almost invariably appear as a part of the auditory perception of direction. A musical note arouses images of a piano, an organ, a cardinal; the sound from a siren provokes imagery of a fire truck, a cotton mill, a city street; the low intermittent tones from a Diesel engine awaken images of a streamlined train, a mill, a ferry boat. Now, these images are projected from the mind and given a setting in a visual field. The cardinal is seen there in a laurel by the balcony, the grand piano is in the music room, the train is on the tracks leading toward the east. It is obvious, then, that such projection of images

aids in one's perceptive localization of the physical source of sounds.

The perception of distance. In case of familiar sounds, the source of the sound is generally judged to be approximately a given distance away. For example, the locomotive is a mile away, the car two blocks distant, the airplane very far off. The observer has learned that, in the case of familiar sounds, the more intense the sound, other things being equal, the nearer the source, while the less intense the sensory experience the more distant the source. It must be noted also that, as a rule, the more intense sounds are relatively rough and appear to assume a pattern that is not uniform, whereas the fainter tones are usually smooth and uniform in texture. For example, listen to a nearby locomotive whistle and then to one which is far away. When, then, a familiar sound is experienced as relatively intense and rough in detail of pattern, the source is thought to be nearby; if the sound is faint and smooth, the source is believed to be relatively far away.

It must be remembered here also that imagery plays a significant rôle. The observer invariably visualizes the physical object and places it in a section, say, of the landscape. When the sound is weak the train is "seen" as located on the river bridge; if the sound is intense, the train is localized on the curve near the station. Errors in visualization, and thus in the perception of distance, occur frequently during changes of atmospheric conditions which cause variations in the intensity of the auditory stimuli. For instance, if the wind is blowing from the train toward one, the sound will be more intense than usual and the train will seem to be much nearer than it actually is; likewise, the distance away may be greatly increased if the wind is blowing from one

toward the train. Radio sound experts rely upon intensity and imagery to produce desired perceptions of distance and thereby make the illusions very effective.

Auditory movement. The auditory perception of movement likewise depends upon variations in the intensity of a given tonal experience, the changes in secondary sensations, and the different types of associated visual imagery. Let us see how such changes occur. Suppose a vibrating tuning fork is placed three feet in front of the observer, and then moved from right to left back and forth in front of him. The intensity will become alternately greater for one ear and then for the other; the muscles controlling the eyes, the head, and other bodily structures may involuntarily tend to cause those structures to follow the supposed location of the physical object; visual imagery will more than likely appear and place the physical stimulus in various positions with reference to the observer and the background of the stimulus. Again, the radio sound expert skillfully employs variation of intensity and relies upon the imagery of the listener to produce so-called illusions of movement. Listen to the galloping horse as it approaches and passes on into the distance, the footfalls of marching men as they come and go, the waves as they rush in upon the shore and recede; all such effects are produced by apparatus which give suitable variations in intensity and which provoke secondary sensations and especially secondary images in the mind of the listener.

Tactual perception. Here again the stimulus error must be avoided by distinguishing, on the one hand, between the processes as such that constitute a perception and, on the other hand, the physical object which may stimulate the sense

organ, for one is here concerned with the psychological processes only. One must constantly keep in mind the fact that the meaning is psychological, not physical, and that one must consequently restrict himself as rigidly as possible to the observation of mental phenomena.

It will be remembered that the pure tactual sensory data are such experiences as warmth, cold, clear pain, light pressure, ache, strain, and smooth pressure. These, when unassociated, are inherently meaningless. From the point of view of sensation, there is no such thing as cold ice, warm weather, a painful tooth, or smooth glass; the associations of various mental data may give such meanings. Moreover, in the field of touch, perceptive space and localization are complex experiences effected through associations. A tactual sensation is inherently extended; usually it is voluminous; the extension is, however, more of the predimensional nature than it is tridimensional in a perceptive sense. Such tactual perceptions as size and localization quite likely develop very early; the skin is plastic and may be folded, one's limbs may be crossed and one's hands may be clasped or they may grasp parts of the body or other objects; the infant constantly moves his hands and feet and seems to live, as it were, in the realm of tactual experience. It is likely that he is unaware of what he is doing as he builds perceptions in the field. But let us turn to some illustrations of tactual perception.

The perception of weight. Suppose one grasps with the thumb and fingers and raises with a movement of the wrist two weights of like size and shape, the first one weighing about 100 grams and the other about 110 grams. The second is perceived as heavier than the first, or the first as lighter than the second. Such a judgment is easily made; but of

what does the total experience consist? It is obviously meaningful experience, for there is nothing inherently "heavier" or "lighter" in touch experiences as such. The judgment must be perceptive, that is, there must be a complex of different experiences which constitute meaning. The primary sensory experience is the pressure on the thumb and finger tips. These pressure patterns differ widely in their extent and in their density. The observer usually judges "heavier" when the patterns are more dense, "lighter" when they are less dense. There are other sensory experiences which should here be classed as secondary sensations. Smooth pressure arises from the wrist joint; faint patterns of light pressure are had from the back of the hand and from the forearm; strain frequently occurs in the throat, as if associated with the vocal cords. These various patterns vary in size and intensity; the observer usually identifies the denser pattern with the judgment "heavier."

Moreover, visual imagery of the stimulus objects enters into the experience. Although the observer can judge with reasonable accuracy in terms of tactual experiences only, his judgments are much more accurate when he permits visual images of the objects to enter. In some way, these images, when combined with the sensory patterns, make the meaning clearer. From the analysis of such a relatively simple type of perception of weights, one can infer that, generally speaking, such perceptions consist of tactual and imaginal processes in combination. One should remember, of course, that the range of such experiences may be very wide in types of processes and in intensity, especially in lifting heavy objects which require a large amount of muscular effort and many bodily structures.

Cutaneous localization. We have said that localization is not intrinsic to touch processes. One can, however, locate with accuracy the position of a cutaneous stimulus. Let a mosquito bite one on the cheek, on the arm, or on the ankle; instantly one realizes where the pain arises and, almost involuntarily, strikes the insect. Immediate visual observation is not necessary to such localization. One cannot speak with certainty about the total number of factors involved in such an experience, for many different conditions may play a part in such perceptions. For instance, there is evidence that reflex action may play a prominent part. Decerebrize a frog by clipping the spinal cord at a point near the brain; with a heavy pin fasten the frog to a wall, and touch, say, his right thigh with a piece of blotting paper soaked with acetic acid; the frog will move the right leg, and if he fails to remove the stimulus in that way he will use his left foot to rid himself of the irritant. This mode of localization on the skin must be accomplished reflexly, for under such conditions the sensory nervous impulses cannot reach the frog's brain. Man likewise relies to some extent upon reflex responses, especially in the case of those responses that are made with accuracy during natural or induced sleep. One lives so constantly, from birth on, in the sphere of touch that it seems plausible that localization of many familiar stimuli should become almost automatic.

But localization cannot generally be reduced to mere reflex action. Obviously other sensory and imaginal processes are ordinarily involved. We do know, for example, that muscular responses occur in the region of a stimulus and, frequently, in many other parts of the body. These bodily movements give rise to secondary sensations. Suppose, for

example, a mosquito bites one on the left arm; in addition to the pain, secondary sensations arise from movements of that arm, from the right arm and hand as they are employed instantly in removing the irritant, from the throat as one speaks audibly or not of the pest, and also very likely from other bodily structures. These sensations appear to converge about the supposed location of the physical stimulus. Even under the unique condition of having one's hand itch when the corresponding arm has been amputated, the impulsive movements are often directed toward the hand rather than toward the stump of the limb where the physical irritation actually occurs. Then, too, imagery appears to add to the perception. Visual and tactual images of the area of the body involved and of the physical stimulus are likely to appear. The meaning, then, becomes restricted to one general area of the body, with the physical stimulus localized at one part of that general place.

It was once thought that "local signs" indicated the location of the stimulus. It was believed that sensory experiences of the same mode, as light pressure, were sufficiently different from each other for one to identify a given sensation as arising from a particular cutaneous area. Evidence offered in support of the theory is, however, not convincing. It is now believed that one has constantly available a mental image of one's body, an image developed through experience and consisting chiefly of data derived from vision and touch. Suppose, for example, a life-size photograph of the observer's own left hand and forearm, with which he is of course very familiar visually, is placed before him, while the hand and forearm themselves are concealed by a screen. When the experimenter touches some point on the hand itself, the ob-

server is able to indicate with accuracy the corresponding place on the photograph. If, however, the observer is asked to point out on a photograph of his back and shoulders, a region with which he is unfamiliar, the point touched on his back, the average error is much larger than that associated with the hand and the arm. The difference in accuracy is likely attributable to the fact that the imagery associated with a familiar part of the body is much clearer than that related to an unfamiliar section. In the case of this illustration, it is obvious that one's imagery, both visual and tactual, is built up much more fully and accurately with reference to one's hands than it is in connection with one's back which is relatively inaccessible.

Cutaneous movement. If an insect crawls along one's arm, or a pencil is drawn lightly across one's cheek, one not only perceives movement but also the direction of the movement. The meaning here is not strictly unlike visual perception of movement. The physical stimulus arouses pressure and perhaps other modes of sensory processes; there occurs the comet-like trail of positive afterimages, more or less long according to the intensity and rate of the stimulus; there are involuntary movements of the muscles associated with the part of the arm or cheek, as well as with movements of the hand which might be used to remove the stimulus, of the eyes which might turn toward it, and of the vocal mechanism which might exclaim about it. Moreover, imagery of the area at which the stimulus occurs and also of the physical stimulus itself generally appears, permitting reference of the moving stimulus to the stationary landmarks included in the image of the body. One thus, from moment to moment, refers the stimulus to various parts of the tactual field as the

pressure changes from one part of the skin to another. In some instances the imagery seems to enter so vividly as to cause illusions of movement. It must also be remembered here that one has learned to interpret movement and the direction of movement in terms of the relative intensity of the pressure pattern, and so one perceives the direction of the movement as corresponding to the direction of the relatively greater intensity of the comet-like sensory pattern. Thus, the perception includes the core of pressure, positive after-images, imagery, and sensations from the contractions of muscles and the movements of joints and other structures.

The perception of oneness and duality. Suppose an experimenter touches the skin of an observer, whose eyes are closed, with the hardrubber points of a pair of compasses, or with an aesthesiometer. If the points are only 1 mm apart, the observer will perceive one point only of pressure. If the points of the compass are separated by small steps, perceptive changes from one point to two points will occur. At first the experience becomes a larger, somewhat elongated single point; then it becomes oval in shape; next it is shaped like a dumbbell, having two enlargements connected by a line of pressure; finally, the two lumps of pressure snap apart, the connecting segment vanishes, and one perceives two points of pressure. The distance which the points of the compass must be apart in order for one to perceive duality varies according to the sensitivity of the skin; on the finger tips and lips the distance is small, while on the upper arm, chest, and back it is much larger. Illustrations of the distance between the points of pressure, in mm, in order to perceive them as two are as follows: the tip of the tongue, 1; the red of the lips, 2; the back of the hand, 31; the forearm, 40; the middle

of the back, 68. In the case of a limb, the limen is larger if the points are longitudinal to the limb than it is when they are transverse to the limb. Moreover, the perception of the direction in which the two points lie requires a still wider separation of the points of the instrument. The compass points must be approximately 25 mm apart before the observer can state accurately the direction with reference to the limb or to the body.

The changes from the perception of one to two may be observed likewise in vision. If the observer fixates two points of light, located either nearby or far away, placed close enough together to subtend a visual angle of less

than $1'$, the two will be perceived as one point of light which is more intense than if only one of the stimuli occurred. Now gradually increase the distance between the physical stimuli; the experience first becomes elongated, then assumes the dumbbell shape, and finally snaps into two separate visual areas. When the stimuli subtend an angle of less than $1'$, they stimulate only one area of the retina; while for the perception of duality to occur, there must be at least a small section of unstimulated rods and cones between the two retinal images.

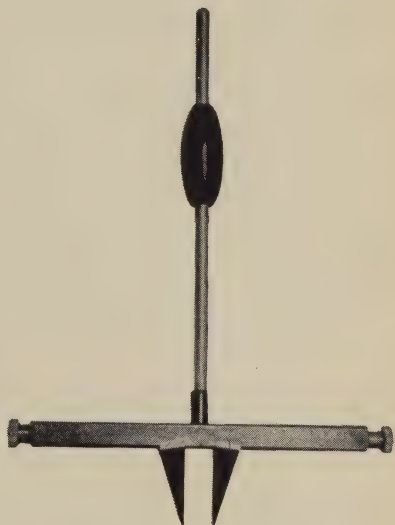


Fig. 74.—Aesthesiometer.

Illusions of duality and magnitude in the field of touch show how tactual sensory experience and visual imagery normally influence the perception of duality. Aristotle showed that a marble held between the sides of the crossed index finger and middle finger will be perceived as two marbles. A pencil placed between the tips of two crossed fingers will

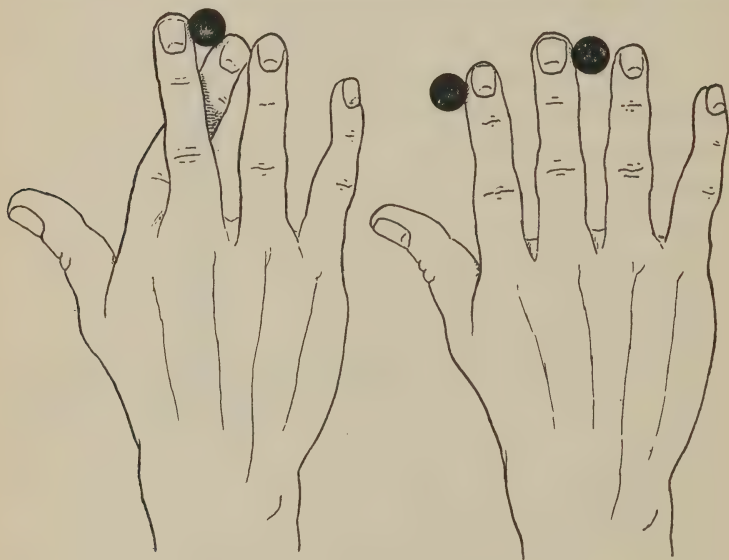


Fig. 75.—Aristotle's Illusion.

be perceived as two objects. Again, if the tips of the crossed fingers are brought lightly over the lower front teeth, it will appear that there are two rows of teeth. One is here judging in terms of old cues normally experienced not between but on opposite sides of the fingers, and the usual modes of imagery accrue despite the fact that one knows that the experience is an illusion. When one explores with the tip of the tongue a cavity in a tooth, the opening seems very large.

The limen of tactual sensitivity on the tip of the tongue is very small; one habitually interprets in terms of touch and vision; consequently, since vision cannot now offer a direct check or correction, the illusion of magnitude occurs.

The perception of bodily movements. One other illustration will aid in showing the composition and the scope of the perceptive consciousness. One is clearly aware of the fact that one can stand erect, walk in different directions, bend the body, and at the same time perceive the position of the body, the direction of its movement, and make such adjustments as may be necessary to establish equilibrium or orientation. Now, how do such complex experiences lend themselves to analysis? So many conditions of body and mind are involved that here only a list of the factors that may be involved is offered.

In the perception of bodily equilibrium and movement one experiences pressures and strains from the soles of the feet and from the tendons and joints of the feet and legs. Evidence of such experiences may be had from normal individuals, and also from abnormal persons who suffer from lesions in the sensory tracts of the spinal cord. In the case of patients having locomotor ataxia or *tabes dorsalis*, the sensitivity of the feet and legs is decreased, and the patient has difficulty both in holding himself erect and in controlling his legs in walking, for the pressures and strains which are normally coincident with walking are weak. Vision also assists the normal person in retaining equilibrium. One normally uses vision constantly to check and correct one's position. If one places the ankles together and closes one's eyes, one will sway slightly from side to side or forward and backward; open the eyes, however, and the body will be

held relatively still. Even the patient suffering from locomotor ataxia can hold himself reasonably still when he is permitted to check and correct his position visually. The semicircular canals, the utricles and the saccules, lying near the cochlea of the inner ear, play a part in equilibrium. Extirpation of the canals of pigeons, for example, causes pronounced incoördination of movements. Congenitally deaf people, who also frequently suffer a pathological condition of the semicircular canals, may in unusual situations have difficulty in indicating bodily position or direction of movement. Then, too, the viscera furnish sensory processes involved in the perception of movement and position. These structures, including the liver, the stomach, and internal organs, are supported somewhat loosely within the body cavity; in this position they may move slightly when the body moves and set up pressure experiences which are localized usually near the body wall. In equilibrium, however, the primary sources of sensitivity are to be found in vision and especially in the deep-seated experiences arising from the muscles, the tendons, and the joints.

In this simple—too simple—outline of perception, we have indicated five factors: first, the associative tendency of mind joins mental processes into what we have called meaning; second, the meaning consists of the sensory core and the context of secondary sensations, secondary images, and, frequently, the affective process; third, the accruing sensory processes arise from various sensory areas, while the imagery springs from mind itself; fourth, the mind establishes habitual associative tendencies, so that certain types of sensory and imaginal context are likely to occur when a certain type of sensory experience appears under a given environmental

situation; and, fifth, the mind may retain as complex experience a given associational pattern and recall it on occasion without undergoing the necessity of constructing meaning *de novo* in every instance. There is, generally speaking, a stability of mental operations; that is, one actually perceives familiar objects usually as one has formed the habit of perceiving them. For instance, words mean about the same from day to day; the tone means the cardinal in the garden; blood is red; snow is white, even if seen at night when the intensity of the light it reflects is greatly reduced. Such constancy of associations prevents vast confusion in the world of perception, for it leaves one with a wide range of freedom from variations in the quality, the size, and the intensity of sensory stimuli themselves.

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CHAPTER XIV

Association and Memory

THE general fact of the association of one thought or idea with another has been recognized since at least the time of Aristotle. Prior to the formulation of the "laws" of association by Aristotle, Greek philosophers had insisted upon an exact, logical sequence of thought, and even memory experts who boasted of their feats of association of numerals and words appeared at the Olympic games and elsewhere. Moreover, philosophers—including even professed materialists—seemed forced to offer an explanation of mental sequences.

It seems advisable, therefore, in the light of various conceptions of mind, first of all to review briefly some conceptions of how thought processes are associated with each other. For example, when one thinks of the first letter of the alphabet, the second letter appears, and then the others in correct sequence come into consciousness. One hears the name Caesar, and then recalls Gallic Wars, the Ides of March, Mark Antony, funeral oration, Shakespeare. The white birch on one's lawn reminds one of a grove of birch trees in New Hampshire, a camp, a lake, a leaping trout. Such associations are commonplace in occurrence; but how do they occur? What is the cause of such sequences of thought? Several answers are available to us.

The neuron-synapse theory. The most popular theory of association is that which presupposes the brain to be the seat of mind and, therefore, the organic basis of association.

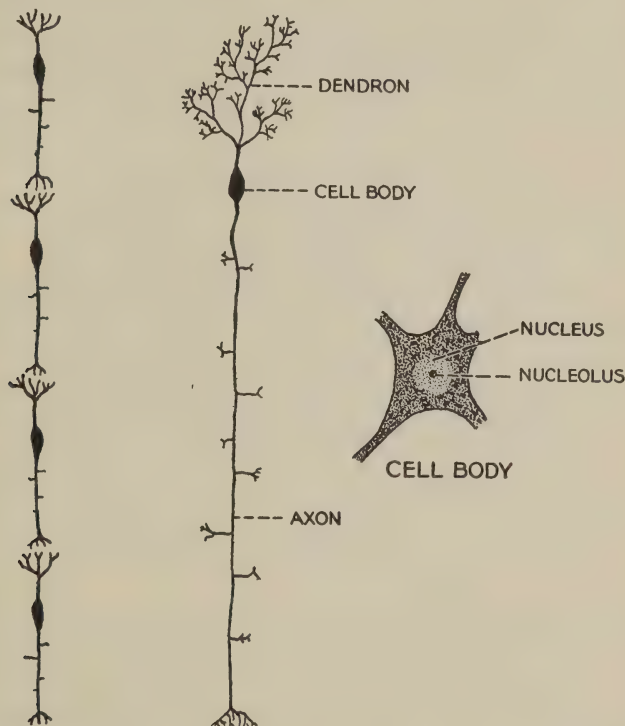
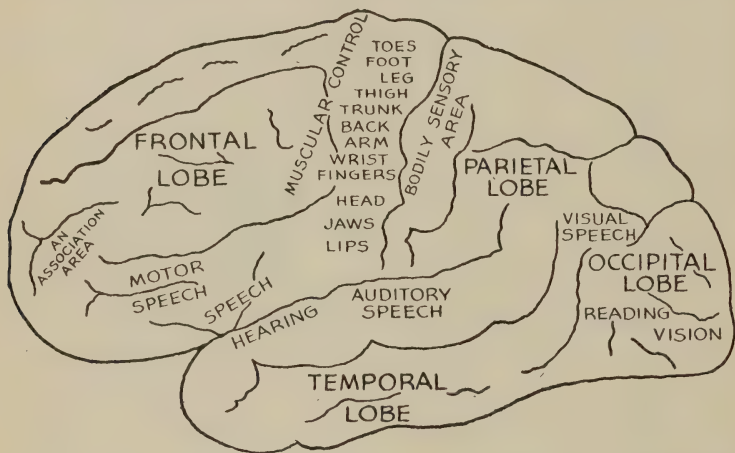


Fig. 76.—The Neuron and Neuron-Synapse Structures.

Some writers go so far as to insist that thought in general consists of the activities of brain structures; others say that mind is only a by-product or epiphenomenon of brain activity, as the light which radiates from a burning candle, or the electricity which emanates from a generator. This theory is plausible because it appears to conform to obvious

facts. For instance, no one knows of mind except in connection with a nervous system; comparative psychology shows a close correlation between mental capacity and cerebral complexity; abnormal psychology indicates, as in the case of brain tumors, encephalitis, and paresis, that the disturbance of cerebral structures causes abnormalities of association; and certain drugs which affect the nervous system

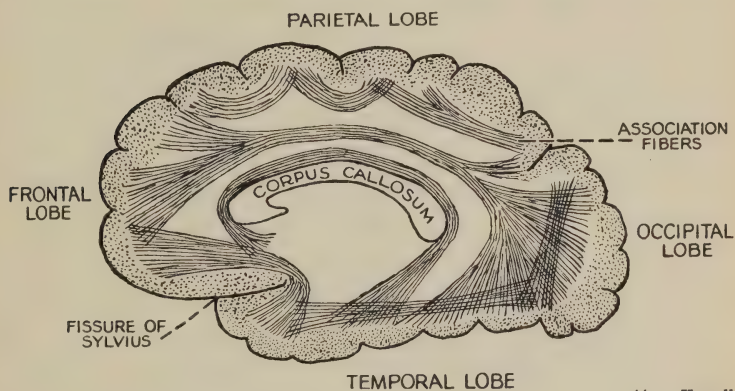


After Warren

Fig. 77.—Lateral View of the Cerebrum, Showing Localization of Functions.

cause exotic imagery or deliria. Moreover, the nervous tracts, the systems of associational fibers, and the vast complexity of the cerebral cortex lend weight to the theory that association, if not consciousness itself, is reducible to a condition of cerebral connections. Furthermore, in support of the theory one finds vast and adequate complexity in the cerebral cortex which consists of thousands of millions of neurons which are directly and indirectly associated with one another.

The neuron is a microscopic nervous unit. This unit consists of a cell body having its nucleus, the nucleolus, the transverse fibers, and the Nissl bodies which some regard as stored up energy. Two types of processes, the dendrites and the axon, grow out from the cell. The dendrite has numerous branches and resembles the root structure of a plant;



After Howell

Fig. 78.—Cross Section of the Cerebrum, Showing Commissural Fibers.

these fibers act as receivers, that is, the nervous impulse always enters the cell over the dendrite. The axon, which consists of one fiber from which branches lead at right angles, transmits the nervous impulse from the cell of one neuron to the dendrite of an adjoining neuron. The synapse lies between the axon of one unit and the dendrite of another. The synapse seems to consist of a very delicate protoplasmic substance which serves as a means of insulation; some regard it as merely a gap between the axon and the dendrite structures, separating them by almost sub-microscopic distances.

Now, the neuron-synapse theory of association lends itself to clear, if inadequate, explanations of how nervous impulses are transmitted from neuron to neuron, effecting molecular changes in the neuron itself and breaking down the insulation or closing the gap at the synapse. Where a series of connections is once established, a nervous impulse, like water

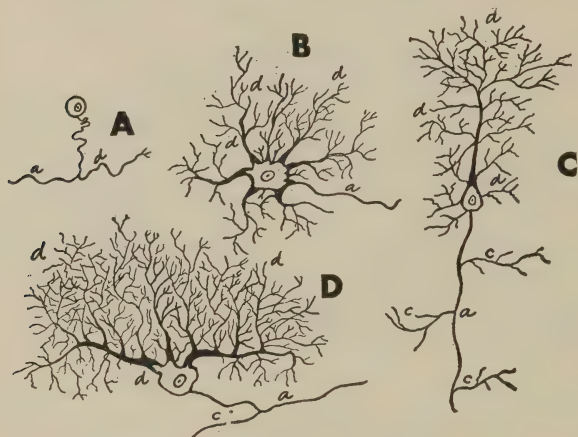


Fig. 79.—Types of Neurons. (Axon, *a*; collateral, *c*; dendrite, *d*. Reference is to the small letters in the illustration.)

flowing along a ravine, may pass that way easily; hence, the ease with which one recites the alphabet or other well-established material. The brain, like a wax record, receives and retains impressions, and the groove is followed later with some measure of ease. Moreover, repetition of the impulse which establishes the sensory impression increases and makes more permanent the nervous channels. Likewise, the weakening and the loss of associations are explained in terms of the partial filling up of the impressions, or the occurrence of obstructions which may block them partially or com-

pletely. Again, such explanations of the loss of memory seem credible. Then, too, nervous impulses are galvanic; sensory impulses, which may arouse consciousness, lead toward the higher nervous centers; nervous substance, especially in youth, is very plastic; and the vast complexity of the cerebral cortex easily affords such scope and intricacy of structure as may appear to be necessary in the case even of the most highly developed minds.

We accept brain as the seat of consciousness, and we may consider it as one explanation of psychological association. There are, nevertheless, other considerations which must not be overlooked. Before brain can be regarded as the full and complete explanation of association, certain difficulties must be removed. For example, one must explain such mental characteristics as recognition, analysis, and evaluation. Moreover, the mind does not function as a mechanical arrangement, however elaborate and alive the brain may be. When pressed to its logical conclusion, the neuron-synapse theory reduces mind to the condition of epiphenomenology, a status which is untenable.

Association of ideas. The usual treatment of association as a combination of ideas is also unsatisfactory when examined in the light of logic and psychological facts. Plato recognized the fact of association and the significant part impression plays in the development and functioning of mind. Aristotle inquired into the nature of recall, and formulated the "laws" of memory, namely, similarity, contrast, succession in time, and contiguity in space. These "laws" seem plausible in the light of everyday experience. Of course, if one sees a face, it may remind one of another face having similar characteristics. If one thinks of Julius

Caesar, one may recall Napoleon; Mussolini suggests Hitler; a Murillo recalls a Rembrandt. Then, too, one seems to recall things of the same order because of contrast. For instance, a midget reminds one of a giant; poverty suggests wealth; the grotesque gargoyles on the exterior of a cathedral remind one of the beautiful images and stained glass windows of the interior.

Contiguity in time operates in the same manner. One remembers the concert yesterday, and recalls that a lady fainted; a visual image of a wrecked automobile arises, and the image of the victim occurs; one recalls the storm clouds, and also remembers the flashes of lightning and the crashes of thunder. Contiguity of two or more experiences in space likewise appears to effect the recall of one when another is remembered. The portrait and the frame, the books and the bookcase, the typewriter and the paper and desk, the street intersection and the traffic officer, the wisteria and the arbor are illustrations of the influence of this "law."

These laws will not bear examination in the light of logic or experimentation. All four are reducible to one, that is, to contiguity or succession in time. Similarity and contrast cannot actually be distinguished from each other. Try to compare two utterly unlike experiences. The midget and the giant are as much alike as they are unlike; the taste of quinine can hardly be contrasted with the distance of a star. Contiguity in time and in space likewise cannot be differentiated. In so far as we know, one may experience only one state of consciousness at any given moment. That state of consciousness may be simple, as a pure tone, or complex, as a photograph or an orchestral production; but, whether simple or complex, it is one state of consciousness at any

given instant. If, therefore, two or more experiences occur simultaneously, they are in reality only different parts of the pattern or configuration which we call one state of consciousness. Moreover, when examined experimentally, the association of experiences is found to consist of simple or complex experiences which occur in immediate sequence. The letter A recalls B; B, C; C, D; and so on, not because of similarity or contrast, or because they occur together in space and time, but because B occurs in immediate sequence to A, and so on. One likewise has experienced Caesar and Napoleon, Mussolini and Hitler, midgets and giants in temporal sequence. The Aristotelian "laws" appeared to be an adequate explanation of the sequence of ideas, hence they were widely adopted and accepted as laws despite the fact that they are scarcely more than common-sense interpretations.

There is, moreover, another objection to the doctrine of associationism. It undertakes to show sequences of ideas only. Now, an idea is in itself a complex experience, similar in most respects to a perception. The problem of association is, then, not restricted to the study of sequences of complex perceptive or ideational patterns, but it of necessity includes the formation of complex patterns themselves. These patterns of meaning are formed; their formation must be accounted for. Furthermore, merely to show that sequences occur is not to give a description of the bond or link which effects the association. Descriptive psychology is under the necessity either of describing that bond, or, by inference from observed relations of mental phenomena, of formulating a law specifying its functional nature. Such a law should apply, if possible, to all associated mental proc-

esses, including sensations, images, affection, meanings, and ideas. It is in experimental work that one finds at least a tentative statement of facts.

The experimental material and method. Let us frankly understand that the experimentalist has been unable, thus far, to examine all factors that may be involved in thought or the association of thought processes. For instance, he is unable to observe the brain or the brain cells in their relation to thought; he merely assumes the existence of some coincident activity. Perhaps it is in brain activity that association occurs. The psychologist takes the point of view not of the biologist but of the psychologist, and examines that which is associated, that is, the thought processes themselves. He then formulates the law of association in view of the observed facts.

The experimental material. In 1885, Herman Ebbinghaus devised the nonsense or meaningless syllable as a type of stimulus object for the study of association. The nonsense syllable consists of two consonants connected by a vowel, forming a syllable which is without context or meaning. For illustration, syllables like zer, yev, leb, zov, vaz, ruz, raj, and tef are practically without meaning. Compare them with meaningful words of similar length like cat, man, dog, gun, and war. The nonsense words seem bare and isolated, just words with which one can link almost nothing from memory as one looks over the list; whereas, the familiar words, which have been learned in a hundred different relations, bring into consciousness scores of meanings. Take the date 1163; there are practically no associations of events made with it; while another, 1776, is rich in meanings. So Ebbinghaus, in using nonsense syllables, was able to study

the development of a group of associations from the outset, for the words were new and no connections had been made between them. He prepared several hundred lists of different length and memorized the lists under controlled conditions.

For such control of conditions the experimenter uses apparatus by means of which the syllables are exposed, one at

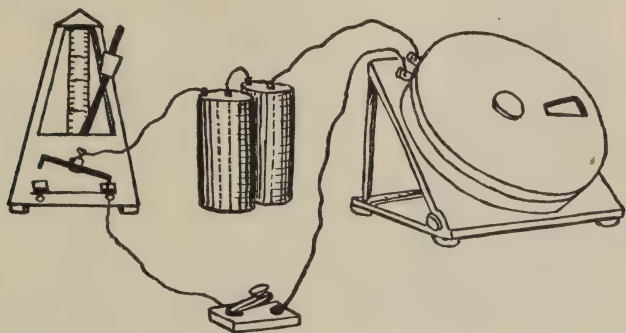


Fig. 80.—Ranschburg's Memory Apparatus.

a time, at a given rate. The Ranschburg apparatus is now widely used for this purpose. It is electrically driven and can be so regulated by metronome control that the lists can be presented at any desired rate; the change of the syllables exposed, one by one, through the slot occurs so quickly that the observer does not perceive movement; unavoidable noise is kept constant throughout the experiment. The observer is isolated as nearly as is possible so as to avoid distractions. In order to avoid disturbances, a sound-proof room is eminently desirable for the work. The syllables must be uniform in size and intensity; the letters must be all capitals or all small, and none should be more saturated in color than another. The observer usually works at the same hour

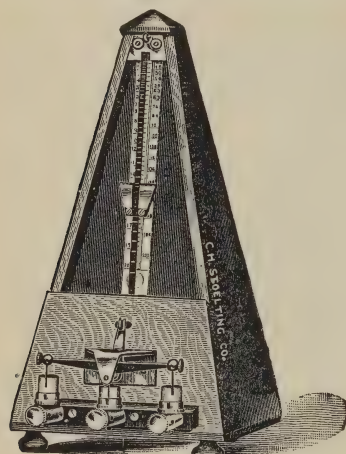
of the day, and in this way avoids the influence of variations in his efficiency throughout the day. With conditions in general controlled, the experimenter varies the length of the list, exposes one syllable longer than another, makes one

syllable blacker than the others, or changes some other factor and determines the differences, if any, that appear in results.

Experimental results.

What were some results of the work with nonsense syllables? We shall, in general, point out some of the more important discoveries.

The law of association. In the simplest form, the law of association may be stated thus: If two psychological experiences occur in immediate



C. H. Stoelting Co.

Fig. 81.—Bell Metronome with Mercury Contact. (The instrument is used to control the rate at which syllables are presented.)

sequence to each other, when the first reappears in consciousness, the second will tend to appear also. More generally, if a psychological experience has associated with it other sensory, imaginal, and affective processes, when that experience reappears there are likely to appear also those processes formerly associated with it. Its operation seems clear. The letters A, B, C, D, E, F have been experienced in immediate sequence; when, therefore, A reappears, B tends to reappear; B recalls C, C brings up D, and so on. Suppose one learns, by having presented to him in the order given, this list of syllables: zer, leb, nev, vir,

mub, yan, vez, zor, cev; when zer reappears, the other syllables will tend to arise in consciousness in the order in which they were learned. They may not appear; interruptions, blocking, and the like may interfere, for mind is easily subject to distractions, but they will tend to reappear. Now, let one apply the law as widely as he may wish.

Of course one thinks of scores of illustrations of the operation of the law. The ease with which one recites the alphabet, the flow of numerals from 1 to 10 and up, the appearance of the meaning or context of images aroused by Wagnerian music, the experience attended by a feeling of revulsion, and lines of poetry which appear in correct sequence are cases in point of everyday experiences. However, lest this appear to be merely a common-sense study of sequence of ideas, one should remember that one is concerned with the psychological processes—sensations, images, affection, perceptions, ideas—linked together by some lawful force in operation which holds them together as the pearls on a thread. It is the total condition, the pearls in order and the string, that must be considered. The pearls are in full view; but what is the force that binds and holds them together?

The associative bond. Until much more is known about the metaphysics of man, no final answer can be had with respect to the associative bond, for, no doubt, the secret here rests in the metaphysical level. This is not strange, for the innermost nature of the phenomena of life must likewise be sought in that substratum. If we hold to the theory of psychophysical parallelism, we may assume, with James, that the nervous system, as one aspect of a man, associates, and that the psychological processes, as another aspect, are asso-

ciated; and then add that, theoretically, it is in the substratum of both these modes of appearance that the law of association actually exists. Thus far, then, one can discuss the nature of the bond only in terms of how it operates.

The associative bond functions somewhat as a one-way street or conduit, in that for the most part the thought processes are associated in the sequence in which they originally occurred. It is a conjunction of the processes with the tendency for them to flow in one direction. Take a familiar example—repeat aloud the letters of the alphabet from A to Z as rapidly as possible. The recital will require about 3 seconds, or only enough time to utter the sounds. Then name the letters in reverse order, from Z to A; the time will be much longer and many pauses and inhibitions will occur. Try again. $3 \times 3 = 9$; reverse the sequence and note the difficulty. Recite a few lines of familiar verse; then give the words in reverse order. Obviously the tendency is for the associations to reappear in the order learned.

The bond is not restricted to experiences in immediate sequence, for there is some relation between syllables, words, or digits that are separated by one or more intervening experiences. For instance, there is some tendency for C to follow A, E to follow C, and even H to follow E. This bond is weaker than that between two experiences that appear in immediate succession. Other things being equal, the more widely separated the experiences in a series the weaker will be the associative tendency between them. Moreover, the associative flow is not wholly restricted to one direction; there is a slight retroactive effect. Although the direction of the associative tendency is usually forward, there is some slight connection backward. This weak relation exists between

adjacent experiences, and it becomes much weaker between remote experiences in a series. The one-direction effect is, then, not as all-inclusive as one first suspects, for one may recall experiences in reverse order. The actual strength of this reverse tendency is hard to determine. It is likely almost negligible in its influence upon sequences of thought. Of course one can easily recall such items as the numerals 9, 7, 3, 1; or the letters Y, S, M, F, A. But it must be remembered, however, that one has experienced such familiar material in numerous ways, and that various associative approaches to such material have been established. The stimulus word "chair" is likely to produce the image "table"; but one has learned "table" in so many ways that a score of avenues may lead to it; even the word "table" is likely to recall the image of "chair." Moreover, the associative complexes may become so involved that the bond functions as between remote or small parts of earlier experiences.

The law of association, as we have stated it for the introductory student, is here perhaps unduly simplified, for it seems to indicate that items are joined clearly in a given order by some psychic force or substance just as pearls are threaded and held together on a string. But, psychologically, even a small fragment of a pearl may lead to a fragment of another pearl or to a string of pearls; a ring may remind one of a friend; the few lines of an artist's caricature may be sufficient to provoke clear images and vivid memories, and even a faint perfume may set up a train of associations. For present purposes, however, it may be sufficient to point out the fact that the associative bond does function as a means by which experiences are joined. It must be understood that the thought processes brought together by the associative tendency may

be the simple processes, as sensations, images, and affection, or they may be highly complex processes, as perceptions and ideas. It, furthermore, needs to be remembered that the associated process may be clear or unclear in consciousness. The items forming the chains of thought, whether they are simple or complex processes, may be full and clear or weak and obscure.

One will ask just what the substance of the bond is. Is it physiological, or psychological, or psychophysical? As has been stated, no satisfactory answer can now be given. It appears that ideas are associated with ideas; the affective process is often associated with ideas; motor activity may likewise subtly start a train of ideas. The occurrence of motor influence is easily shown; for instance, trains or currents of images, as catchy tunes, may be set up by bodily rhythm in walking. As has been stated already, physiological activities and psychological processes are so intimately connected that one can effect only an arbitrary separation. The bond appears to be both physiological and psychological; perhaps it transcends either. Meanwhile, we can note ways in which it operates.

The memory span. How many nonsense syllables or short words can be recalled in correct sequence if the list is presented or read only once? This question must be answered in terms of the maximum length of the list of syllables or words, for, when the list exceeds the memory span, the list becomes confused and very few, if any, syllables can be recalled. For example, when a list of 4 syllables is presented once, the observer can easily recall the list; but if a list of 16 syllables is presented one time the observer may remember none or only one or two. It appears that the normal

span is 7 nonsense syllables. When, however, familiar words or numerals are used, from 8 to 12 may be recalled. As we have seen, however, familiar stimuli have already been learned in various ways, which accounts for the longer memory span when meaningful material is used.

Of course, there are many variations from the normal memory span of 7 syllables. There are exceptional individuals—children and adults—who have photographic memories and who can reproduce almost any series of stimuli which they may see or hear, whether it be numbers, prose, or verse. Idiot savants, helpless in most other respects, can remember incredibly long series. One such person could reproduce at the piano any musical number, errors and all, which he had ever heard played on that instrument. There are memory schemes which aid one in recalling long series of words, as well as in naming any member of a list of words, as the seventh, the ninth, the thirtieth, and the fourth, that may be named at random. But such memory schemes or memory systems are only ways by which the operator associates a given word with a certain part of a scheme or framework which he has already committed to memory. The expert merely places, as it were, a given item of the list in a certain pigeonhole. Such schemes, as well as efforts to improve one's memory by practice, do not increase one's native capacity to memorize; they are merely handy tricks which may be employed in particular instances just as when one wishes to remember the address 32 Broad Street, he associates it with his waist line which requires a 32-inch belt.

The length of the series. If the normal individual, after practice, can repeat in correct order a list of 7 nonsense syllables after the list has been presented one time, what will be

the effect of increasing the length of the series? One might expect that, since 7 syllables can be recalled with one reading, a list of 14 syllables should require only two readings, a list of 21, three readings, and so on. But this is far from true. If the list includes 10 syllables, confusion occurs so that perhaps only the first and the last members of the list are recalled even after two or three presentations. The number of presentations of the list and the time required to learn the list do not increase in direct proportion to the increase in length of the series; in fact as the length of the series is increased arithmetically, the number of presentations and the time required for learning are increased somewhat geometrically. In general, for example, a list of 7 syllables requires 1 reading, 8 requires 2, 12 requires 3, 16 requires 6, 20 requires 8, 30 requires 15; a list of 7 syllables requires only 7 seconds, 12 requires 90 seconds, 15 requires 200 seconds, and so on.

Variations from the number of repetitions and the time specified here must be expected with different individuals; but, in general, we may say that with an increase in the length of the series the learning process becomes much more difficult. A cause for the increase in difficulty is not hard to discover. With the series of 7 syllables, there is almost no fluctuation of attention, there is opportunity for very little disturbance, and there exists no appreciable interval of time in which forgetting might occur. A list of, say, 20 syllables gives opportunity for such factors to enter. It is known, for instance, that attention usually fluctuates about every 3 seconds, and this shifting may interfere with learning. It is also known that forgetting begins very quickly, and that the amount lost is much larger at first than later.

The rate of presentation. A list of nonsense syllables or of meaningful words can be presented too slowly or too rapidly to be learned effectively. If the items of the series are shifted too quickly, there appears to be inadequate time for the full development of the conscious process and insufficient opportunity for the impression to become set in the mind or nervous system. The situation is somewhat like a moving picture film when it is run off so rapidly that one observes no images clearly and recalls no scene distinctly. If the series of syllables is presented too slowly, the observer's attention fluctuates so that between any two syllables he may be attracted by extraneous objects of thought, as would occur if the moving picture film were run off very slowly. The optimum rate appears to be approximately 2 syllables every second, which is usually rapid enough to keep the observer's attitude constant. At the optimum rate, then, the next term in a series springs into view before one has time for extraneous associations to occur, and the entire list will be presented in the time required to effect a minimum of waste.

The position in the series. As we have already noticed, various conditions affect the learning process. If we think of learning as the formation of impressions, then many factors may cause deeper impressions at some parts of a series of syllables than at others. For example, the first and last syllables of a series of, say, 15 syllables are learned first. The initial syllable comes into consciousness with a suddenness that is the equivalent of novelty or a shock; the observer somewhat eagerly awaits the appearance of the first word, hence his attitude is favorable; no preceding syllable hangs over as a memory afterimage to interfere with its reception. In the case of the last syllable, this term of the series has the

advantage of longer time; no other subsequent term drives it out of consciousness, and it therefore has time to set or become fixed in mind. It is a well-known fact that learning is more effective when the impressions are given an opportunity to become established. If, for instance, a sudden interruption occurs immediately at the end of a list, the normal rate of learning with reference to that list will be lessened, or the process of learning may even be blocked. In many such instances retroactive amnesia occurs. It appears that some force destroys whatever impression may have been made. On the other hand, if a list is learned and the observer is permitted immediately to rest, retention is enhanced. Lists learned, for example, just before the observer goes to bed at night seem to become more deeply fixed during the interval of rest than do lists of similar length when the period of learning is followed immediately by some other work. These results appear to occur with meaningful material just as in the case of nonsense syllables.

The variation of emphasis. In addition to the influence of the position of a term in the series, many other modes of emphasis occur. If the list of nonsense syllables is prepared on a typewriter, care must be exercised to have every syllable composed of the same type of letters and have the same color intensity; otherwise the term having a difference in type or color intensity will be more attractive and receive undue emphasis. Use, for example, darker ink, or red ink, or capital letters in one syllable; that syllable, by virtue of intensity or novelty, will make a deeper impression in memory. Change the position of one syllable in the exposure window from horizontal to diagonal; again, the effect of novelty will

enter. Give one syllable twice the usual length of time of exposure, and it will be the item most likely to be remembered first. One needs only to be reminded of the widespread employment of such methods by public speakers, advertisers, and others in public life, and of the variation in the emphasis placed upon words in private conversations to realize the widespread application of different modes of emphasis.

The distribution of readings. If one wishes to learn in the most effective manner, one should follow certain optimum methods. Work with nonsense syllables and other materials shows that a distribution of the readings over a reasonably long period of time effects a saving in the time required for learning and at the same time makes retention more permanent. Suppose 20 readings are necessary to learn a list of 30 syllables when the series is learned at one time; only 14 readings may be necessary when that list is presented twice each day. Not only is there saving in the time required to learn the list when the presentations of the list are distributed, there is also more efficient retention of the list. In some way the impressions are made with a smaller number of repetitions, and they also become better established in mind. This work with meaningless syllables is typical of what occurs with meaningful material. Let us take familiar illustrations. One crams immediately before an examination, but one soon forgets almost all one learns under such pressure. Suppose, however, one wishes to memorize permanently a poem. If one reads it twice today, twice tomorrow, and so on until it is learned, and then reviews it, say, once each week for a month or two, the poem

will become so fixed in mind that it will likely never be forgotten. Cramming may be of some value in an emergency; it certainly is not generally advisable.

The attitude of the observer. Attention seems to be prerequisite to the formation of associations. One sometimes comes to the end of a page in a difficult book and discovers that he remembers nothing on the page; the page has not attracted attention, the words have not been in consciousness except vaguely or, as we say, in the obscure level of consciousness; consequently no appreciable impression was made. Likewise, when conditions are arranged so that the observer's attention will not be attracted strongly or constantly to a list of syllables, the time required to learn the list may be doubled or increased to such an extent that learning seems impossible. Numerous influences may prevent one from having the right attitude. Ill health, a too-warm or a too-cold room, poor ventilation, uncomfortable furniture, noises, fatigue, poor vision, distracting ideas, anticipating a ball game or a vacation, and the lack of motives may distract attention and make the opportunity to learn ineffective. On the other hand, the absence of conditions that may interfere and the existence of strong motives facilitate the learning process. The wish to avoid pain, the desire to make an excellent record, and the urge to become scholarly are some ways in which a desirable attitude is obtained by many students. Unfortunately, in many instances examinations have to be employed, as electrical shocks are administered to a turtle in learning a maze, in order to furnish a motive to some members of a class. In case of nonsense syllables or meaningful material, when there is no intent to learn or no attentive attitudes, learning is generally very ineffective.

The part versus the whole in learning. In learning a reasonably short poem or section of prose it is better to learn the material as a unit rather than to break it up into several sections and learn each part separately. If a poem of 50 lines is divided into 5 sections in order to be memorized, some parts will be repeated more than others, and so become over-memorized, while other parts will not receive enough emphasis and will not be adequately memorized. Besides, under such conditions, wrong sequences of words will occur which will mislead one when he undertakes to recite the poem. When, however, the material to be memorized is very long, it is better to break it up into several parts, memorize each part separately, and then establish the memory bonds between them. A poem, for example, of 200 lines should perhaps be learned in sections of about 50 lines each; but after the sections are learned, they must be joined carefully in correct sequence, for otherwise they may remain in mind as four separate, unconnected poems.

Retention. Thus far this discussion has been concerned primarily with the nature of impression; very little has been said about retention of the materials learned. If one undertakes to discover the extent of retention, one must take into consideration such matters as differences in materials learned, the conditions of learning, criteria of reproduction, and human individual differences in ability to learn and retain. In general, the problem is that of determining how much of a given section of material, learned under certain conditions, can be reproduced after a specified amount of time has elapsed.

Two experimental standards are generally used to measure the amount of learned processes that one may reproduce: first, the actual reproduction of the items learned, and, sec-

ond, the recognition of the stimuli when they are again presented. Ebbinghaus, working with nonsense syllables, learned the list so that it was repeated twice in correct order. In this way he avoided inadequate learning and overlearning. Then, after stated intervals of time had elapsed, he endeavored to repeat the list. He discovered that the amount of loss is very large at first, then becomes progressively smaller, and never becomes absolutely complete. For example, the loss during the first day was about 60 per cent; during the second day, 10 per cent; during the third day, 5 per cent; and so on until, after about 6 days, no further appreciable loss occurred. Despite the fact that some amount of relearning may occur in such work, it appears that there is a small amount of the associative bond which is permanently retained. It is obvious that meaningful material is retained better than nonsense syllables, for the number of associative bonds with meaningful items is so much larger and more adequately established than is the case when nonsense syllables are used.

When recognition is made the criterion of retention, the loss is very much less than it is when reproduction is the criterion. In an experiment in recognition the items are presented once, and then re-presented in order to discover whether or not the observer recognizes them. In the case of a large percentage of the stimulus objects, one presentation leaves enough impression for the observer to recognize the object when it is presented the second time. One impression, therefore, seems to be sufficient to touch off the memory process. One knows, for instance, that it is much easier to recognize a name, a word, a face, or a list of words than it is to recall such items of experience. In the case of

recognition, the stimulus touches off the recognition aspect of the memory process, which is only a small part of the total complex processes that may be involved in reproduction.

The fact that the curve of retention shows a final stage in which no appreciable loss of association occurs suggests the apparent permanency of the associative bond. Does one completely forget anything he has learned? Does the normal person suffer effacement of any associations actually established in mind? One immediately thinks of reports, for the most part unauthenticated, of old people who during illness repeat language heard only during childhood, the recital during delirium of prose or poetry read only one time, and the recall during hypnosis of old experiences which the patient could not otherwise relate. Ebbinghaus offers better evidence of the permanence of associations. He learned sections of Byron's *Don Juan* and did not refer to some of them for 22 years. Although he could not recall any part of the selections at the end of this long interval, he relearned them with a saving of 7 per cent. The associative tendency had in some way retained a small part of the original impressions.

Of course one recalls only a very small percentage of the items, as such, of one's experience. Think, for instance, of the few events of yesterday that you can reproduce. Some few experiences can be recalled; yet one formulates a summary or general notion of the experiences of the day. Thought in general is composed of the data of past experience, associated, recombined, readjusted, recalled, and recognized as past experience or not. It must be noted that inability to recall is not identical with effacement. Associations may become weak, through age and disuse; they may

never be brought into use again; but there is some reason to believe that the normal person never absolutely forgets anything he ever learned. In the case of paresis, however, or some other disease in which deterioration of cerebral tissues takes place, the permanent loss of associations does occur.

Inhibition. Many different conditions may influence the associative tendency. We have already seen that the attitude of the individual greatly affects the formation of impressions. As a rule, the poorer the condition of attention, the weaker the impressions that are made; the clearer the condition of attention, the more effective and deeper is the process of impression. Moreover, in recall, attention gives a "set" to mind and body which facilitates the functioning of the associative tendency. One has only to recall in this connection one's ability to remember when under the pressure of an examination or when delivering an important address; attention to the subject in question is intense, and, as a consequence, the associations appear in abundance. Nevertheless, in many instances various modes of inhibition of associations may occur. We shall mention three types.

Retroactive inhibition. Retroactive inhibition is the condition in which the process of forming associations seems to stop some time prior to the moment at which one's experiences cease. For example, one's conscious experiences may stop at ten o'clock, but one may be unable to recall any experience that occurred later than ten minutes of ten. A sudden shock or a blow on the skull, say, not only stops the flow of experiences, it also causes a retroactive weakening or destruction of earlier associations. If an electrical stimulus or some other sudden form of distraction is unexpectedly

applied to one while he is reading a list of words, the association of the words and, therefore, the ability to recall them are not likely to occur. It has also been discovered that a short period of rest, immediately after a list of words has been presented, is advisable. It appears that some amount of time is usually necessary for the association to become established; hence, if this process of fixation of impressions is interrupted, retroactive blocking occurs. Thus, one can be thrown from a horse and fail to remember that he approached and mounted the horse. One may experience an automobile wreck and not even recall having left the house to enter the car. One may report that he has no memory of having played the last quarter of the football game at the end of which he suffered an injury. Amnesia in connection with such experiences does not mean that one was unconscious during the interval in question; the usual associative bonds simply did not become established.

Blocking. The blocking of associative tracts already well established is a common occurrence. Who has not found himself unable to recall a name or a date with which he is perfectly familiar? Some people have forgotten their own names; others could not recall the names of their children; lecturers have been unable to recite simple facts. In general, the explanation is simple. No two states of consciousness can exist simultaneously in one's mind. When one state gains a place in consciousness, another state must await its turn. Thus, for example, one meets an old acquaintance and the thought "I cannot remember his name" blocks the appearance of the name itself. Emotional disturbances frequently do not help matters any. They may arouse the thought "I am embarrassed," and that state of consciousness

further prevents the appearance of the name. Likewise, various distractions and fears in the class room may inhibit necessary sequences of thought. Moreover, many people permit thoughts about the possible consequences to themselves or to others to forestall thought about a problem in question. Many students thus get in their own way. Introversion is not a condition to be desired.

Terminal inhibition—that is a temporary inability to think of some object, make a decision, or perform some simple act—is not unlike forms of blocking. A simple and familiar answer may be ready in reply to a statement, but something interferes, interrupts, or cuts across the train of thought so that the answer cannot get into consciousness. Ask one brusquely what his name is, and he may be so confused that he cannot recall. Watch one as he seems unable to decide to use the pepper or salt first, to order tea or coffee, to go through one door or the other, or to choose between some other simple matters. Observe one's indecisions when he is embarrassed. When such conditions of indecision occur, it is likely that some emotional condition or other mode of distraction interferes and inhibits the thought process that otherwise would have appeared. The number of extraneous influences, bodily changes, and ideational conditions that may cause terminal interference is legion.

Recognition intrinsic to memory. In our discussion of the memory image it was stated that, technically speaking, recognition is an indispensable characteristic of memory. Of course an experience may be reproduced without being identified as an old one. It is because of this fact that one may have imagery or ideas arise out of mind, and believe them to be entirely new. In unusual instances, a short story may

be related as a creation of the writer's mind when, in fact, it is the unrecognized reproduction of a story read many years previously. A student composed the music for a college song which he wrote but fortunately then discovered that the music was a section from a classic which he had learned years before. In view of such a variety of types of reproduction, psychologists define memory so as to make the feeling of familiarity or recognition an indispensable characteristic of the experience. One may, then, not only remember—one may recognize a face, a photograph, a car, a house, a street, a voice, a perfume; and when recognition occurs a change in the total complex of consciousness, whether it be perceptive or ideational, obviously occurs. When one recalls and recognizes an old experience, something over and above the mere perception or minimal associational reproduction is present. What is this recognitive consciousness?

We have seen that perception is a complex experience consisting of many psychological components. It was also noted that numerous bodily changes may occur in connection with a perception. But a perceptive experience alone may not embrace the feeling of familiarity. Moreover, the reappearance alone of images does not conform to our definition of memory. The recognitive experience is not only perceptive or imaginal, it is colored with a feeling of familiarity. This feeling of familiarity is, in all probability, in large measure the affective process which gives the experience the feeling quality of pleasantness or unpleasantness. As we have seen, the affective processes appear to be localized usually in the chest and abdomen and are characterized qualitatively as bright pressure and dull pressure.

The feelings of relaxation, ease and comfort, or of repulsion, avoidance and discomfort can be reduced in part to conditions of bright pressure and dull pressure respectively. If the feeling appears, recognition occurs; if the feeling does not appear, recognition does not occur. Vagueness of feeling brings uncertainty of recognition, while intense conditions of feeling give certainty to memory. One who is partially lost has a vague feeling of familiarity when he finds himself in the presence of objects normally very familiar to him; one who is completely lost suffers such confusion of mind that he does not recognize his friends, his home, or members of his own family. One predominant characteristic of the type of aphasia in which the patient loses his identity is the inability to recognize.

But suppose the feeling of familiarity occurs when one observes an object or a landscape which one has never seen before. Just such falsification of recognition does occur; it is known as paramnesia. It is an illusion of feeling which is not uncommon among psychopathic individuals, and which normal people may experience when in a condition of fatigue, strain, or unusual emotionalism. The abnormal patient may recognize any man as her long-lost husband. The normal person may recognize a street or a landscape which he has never before seen. When one is absorbed in conversation, one may feel that one has paid for the cigars, or that he mailed the letters when in the post office. Some sensory or ideational experience is adequate to touch off or arouse the feeling of familiarity and thus cause the illusion. Hence, we remember things that could not have happened, and we believe that we have completed acts which were left undone. The occurrence of paramnesia is widespread.

General occurrence of the law of association. One may make the error of believing that the law of association functions in connection only with terms learned in sequence, as in the case of a series of nonsense syllables, the letters of the alphabet, or a list of numerals. One had as well think of restricting the law of gravitation to gross physical objects. Mind, we repeat, does not consist of a vast number of sensory stimuli and images only; it includes an almost infinite number of conscious processes, some of which are elementary while others are exceedingly complex. These states of consciousness, whether elementary or compound, are active phenomena that may become interrelated in an inconceivably intricate manner. The associations or interrelations are effected by means of the law of association. What are some illustrations of the scope and functioning of this law?

The law of association is a descriptive formula which shows how the mental elements are conjoined. Let us assume, at least provisionally, that the earliest experiences of the infant child are elementary, that is, simple sensations of touch, taste, and so on. But these sensations do not remain isolated from one another. Of necessity they are experienced simultaneously and form a sort of fusion or mosaic, or they occur in immediate sequence and permit the establishment of the associative bond. Then, too, images arise, and the affective process appears. These elements likewise become associated with sensation and with each other. Most likely, then, it is in this manner that one's earliest experiences become joined together, that the associative bonds are thus formed, and that the first stages of meaning occur.

Meaning or perception we defined as the sensory core and its context of secondary sensations and secondary images. This combination is effected by mental set or brain habit.

What is this mental set? Perhaps, as we pointed out, many different factors may be involved, but one may be reasonably certain that the associative tendency is at the heart of the matter. Meaning is too consistent; it becomes too habitual, like the rote appearance of letters of the alphabet, for it to be otherwise. The sequence of meanings is also a result of interrelations of experiences. Read a line of print; the visual stimuli set up a chain of related meanings. A series of ideas, upon examination, is found to have items or fragments of items which have been associated. Philip of Macedon, Alexander the Great, Caesar, Epictetus, Marcus Aurelius, Napoleon, Foch, Washington, Lee, Mussolini, Hitler, Japan, scrap iron, China may seem unrelated at first, but one has in one way or another formed some associative link between them.

Emotional states, as complex as they may be, are greatly influenced by the law of association. It is no accident that causes a weak color, as a faded yellow, to be unpleasant day after day. Likewise, it is not chance that causes a Beethoven sonata, a sunset, a tree, or a book of verse to arouse a pleasant emotional state. There is a reason why a man dislikes a blond or a brunette, or rebels at taking orange juice. Early associations of an unpleasant nature persist. A blond nurse may have frightened him; he may have been given bad medicine in orange juice. The pages of abnormal psychology are filled with reports of the persistence of emotionalism as related to sensory or imaginal experiences, even when such experiences are extremely vague or fragmentary.

It may be said, then, that the law of association operates in connection with almost every state of consciousness, effects modes of combinations, makes recall possible, and forms a basis for the development of complex and intricate thought.

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CHAPTER XV

Attention

THE actual nature of the attentive consciousness has been widely misunderstood. Nonscientific and popular discussions of mind have been both inadequate and misleading. Common sense here, as in most other instances, has not addressed itself to a statement of scientific facts; it has preferred to follow popular conceptions of the mind. What are some of the popular notions of mind, particularly those related to common-sense opinions about attention?

Popular conceptions of attention. It is generally believed that mind is unrestricted in its activities. It is conceded that the physical and the biological realms are subject to law; activity in those fields is definitely restricted by the very nature of physical substance and mandatory natural law. Mind, however, is not material substance; it is not circumscribed by some law or force which directs it. Irrespective of one's training or immediate environment, the mind can function as it may will to do. Can one not rise above his training? Is it not possible for one to change one's mode of thought? Is it not possible for one to turn, as it were, in the other direction and thus completely alter, reform, or revise one's mode of thought? The weather may be very hot; it is vacation time; one's colleagues have gone abroad, to the coast, and to the mountains. Is one not able

to dismiss thoughts of Paris, Atlantic City, the Great Smokies, and even the weather in the interest of completing one's work? Can he not ignore whatever he desires to ignore and devote himself to any chosen task? When one discovers a new interest or ideal, obviously the mind turns away from other claims, shifts conflicting contents of mind to one side, and ardently follows the new course.

It is, moreover, widely believed that the human mind is dualistic in nature. There is, on the one hand, the mass of data or states of consciousness; on the other hand, there is will, which is the directing force or principle within the mind in general. This force is personified and regarded as a manikin, that is, a little mind which sits somewhere within mind and directs mind in any desired direction. This manikin mind plays the same general rôle as that of the pilot of a boat who determines the course to be followed, or that of a switchman in a railway yard who sends trains over one track rather than another. This manikin mind is regarded as the will or its equivalent; and of course the will must be free to direct thought as it chooses. So the writer can ignore the heat and dismiss the lure of Mt. Mitchell and Little Switzerland; by the use of will power he can substitute other objects of thought for them. He can drive himself to the work in hand, just as he could turn from pen and paper to other matters if he willed to do so.

Attention is, then, popularly thought to be dependent upon a separate faculty of mind known as the will. Attention is something given by mind, directed by mind, controlled by mind, focused by mind upon some object of perceptive or imaginal thought. Attention, moreover, is regarded as capable of exercising the power of mental concen-

tration, as a lens may focus rays of light upon a small area. Consequently we have various terms like focusing attention, the power of concentration, voluntary attention, and involuntary attention. Belief in the existence of all such characteristics rests upon the assumption of the existence of a mental entity or faculty, separate from the general states of consciousness, which possess such freedom as may be necessary to focus, to concentrate, or to direct states of consciousness as it wishes.

The only trouble with this popularly held opinion of mind is that it is not correct; certainly it has no supporting evidence derived from descriptive science. Science knows nothing of separate faculties or compartments of mind; it has as yet nothing to offer as a description of will. It may be, if one is permitted to turn for a moment toward metaphysics, that scientific psychology may point out a road to freedom, but it now makes no pretense of offering a separate and free mental faculty as such which acts as a director of the mind. The fact is that mind, as exhibited in its most elementary and in its most complex modes as well, functions according to its own essential nature—a nature inherent alike in the elements and in the complex forms of mind.

Another misleading mode of treating attention is that found in many of the discussions of attention as related to mental efficiency. Of course attention facilitates learning. There is very little, if any, impression or learning during a condition of inattention. The attitude of the learner must be favorable, or potential stimuli will not gain a place in consciousness. For instance, try to address an audience when a fire signal is sounding, endeavor to lecture to students while a circus parades along a nearby street, or try to learn a long

list of nonsense syllables when you are fatigued. But discussions of the value of attention no more show what attention is than to say that ambergris is very costly is to specify the chemical nature of that substance. It is necessary to turn to scientific psychology with our inquiry about attention.

Scientific psychology and attention. Scientific psychology assumes that the mind is limited in various ways. For instance, the mind is restricted by the individual's inherited capacity. Moreover, it cannot function beyond limits set by its data at a given moment. It also operates within the domain fixed by its own laws. Furthermore, one's environment of a given moment greatly influences one's thought. As Herbert Spencer pointed out, perhaps one can think what one wishes, but many influences converge to determine one's wish. Why not turn to the mind, therefore, as we now understand it in our effort to discover the nature of attention? We have studied the elementary mental processes, namely, sensation, image, and affection, and discovered their modes of behavior. We have examined perception as a type of mental compound, and noted the modes of formation of such complex states of thought. The law of association also was surveyed, both with respect to its nature and its application to mental combinations. It appears from our examination of mind that mental states consist of sensations, images, and affections which occur in simple form or in combination, and that both the simple and the complex states are subject to psychological law. It may be that our survey has included the essential characteristics of mind, and that we have now only to study various configurations or patterns of mind and conditions associated with their appearance. The problem may consist, therefore,

not of undertaking to discover some new psychic force or faculty, but of observing and describing the pattern of consciousness during a state of attention, and in stating the process of development of this unique mental configuration.

Casual observation may suggest a mode of approach to the problem. Let one observe his mental states for a few moments. He will notice that the loud sounds from a passing train claim a place in consciousness, completely crowding the printed page of the book, or reflection upon a historical fact, from one's mind or else pushing all these into the background of consciousness. The moving picture proves to be so fascinating for one that members of the audience hardly exist for him. The novel is so engaging that the dinner gong is not heard. The game of chess becomes so absorbing that the player does not realize that he is eating a box of chocolates. The football player is so attracted by the game that the pain from a fractured collar bone is excluded from his consciousness until after the close of the game. Now, these and other illustrations suggest that one part of the field of consciousness is clear while the other areas are obscure. Notice even a child as he is fascinated by a toy; call him, and he may not hear; the toy-experience is so clear in his consciousness that, for the time, nothing else seems to exist. What is the nature of this pattern of consciousness that is found under such conditions? How may this arrangement of mental processes be described?

The levels of clearness. Sir William Hamilton, an eminent Scottish philosopher of almost a century ago, pointed out the fact that, if one merely glanced at a handful of marbles thrown on the floor, one would see clearly about six marbles only, while an indefinite number of others would

be in the background. Extensive experimental work within recent years verifies the belief that the mental state during a state of attention consists of two—and only two—levels, the clear and the obscure. These two levels are joined to each other, but the clear level rises sharply above the obscure level. Generally the clear level appears as a distinct area against an

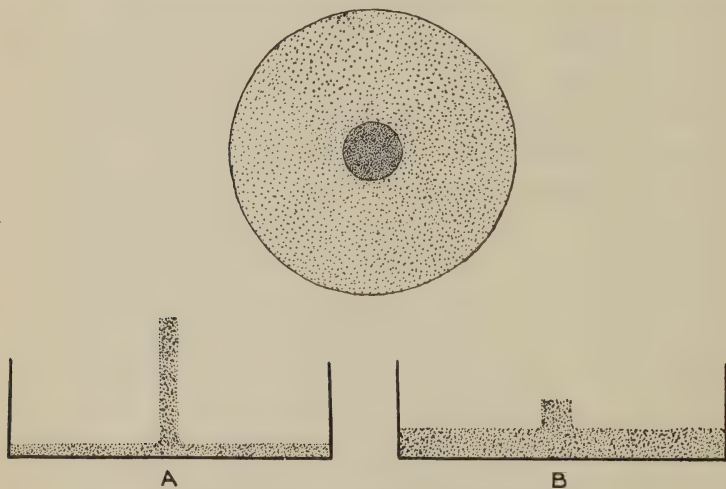


Fig. 82.—The Levels of Attention.

indefinite and obscure background of the field of consciousness. Let us take a familiar illustration, that is, the discovery of a hidden face in some section of a puzzle picture. At first one area or another may be vaguely clear, or the whole picture may be relatively clear. Then, when the hidden face is suddenly discovered, the face stands out in clear and bold relief, with every part distinctly outlined; it is in such relief that it reminds one of a plaque resting against the page. The remainder of the picture recedes into the background; it is there as a vague and indefinite part of the field of expe-

rience; it exists, which is about all one can report about it. If one resorts to diagrams in an effort to show the relation of the two levels, one may give the familiar figure showing a cross section of the "stream of consciousness," and also the figure showing two concentric circles which represent the clear and the unclear areas. In the first figure, a section of the stream is shown as rising above the other area of the stream; while in the second figure the region embraced by the small circle designates a clear column rising sharply from the vague general background outlined by the larger circle. What is the pattern, then, of the field of consciousness during a condition of attention? The answer is that the attentive consciousness, when defined descriptively, consists of sensory or imaginal clearness.

Sensory clearness. We shall, therefore, define attention as sensory clearness, rather than in terms of will or some other force, for we can observe and describe the pattern of the attentive consciousness. What do we mean by sensory clearness? Again, let us resort to simple illustrations. We saw that, when the hidden face in the puzzle picture was discovered, the face stood out in bold relief visually. The same type of change in sensory clearness occurs in other sense fields. The ticking of a clock may suddenly claim attention, and, when this occurs, the sounds become unusually loud. Of course the physical intensity has not increased; but, psychologically, the sounds have become unusually distinct. One is attracted by the hissing of a radiator, and the noise becomes clear. One is attracted by the slow dripping of water in the drain pipe, and the sound is annoyingly loud. A faint offensive odor or taste attracts one's attention, and then pounds and clamors in consciousness. The slight irri-

tation in one's nostrils or on one's scalp becomes so clear as to cause one to sneeze or to seek to remove the irritant. Now, it must be remembered that such experiences generally form one's background of consciousness; it is only when some one of them becomes clear that one easily identifies it. For illustration, perhaps almost all of the time one is vaguely aware of pressures and strains and aches arising as from different parts of the body; they constitute to a large extent one's psychological ego at a given moment; but they exist vaguely in the fringe of consciousness until some ache or pain suddenly claims attention and occupies the clear level. Then it is there; it becomes sharply outlined; and it forces other objects of thought into the obscure area.

Imaginal clearness. The attentive consciousness is usually discussed more at length from the point of view of sensory clearness than from that of imaginal clearness, for sensory clearness is more easily described than imaginal clearness and furnishes one with more illustrations.

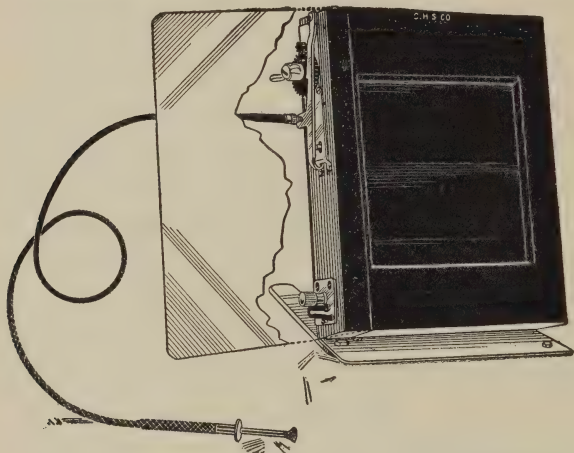
But the attentive consciousness exists just as definitely in the form of imaginal clearness. In the case of sensory clearness, the sensory stimulus becomes clear in consciousness; during a condition of imaginal clearness, an image or an idea occupies the clear level. One has, then, only to substitute an image or an idea for the sensory experience, and the image or the idea occupies the clear level, just as the sensory process did in the case of sensory clearness. One may, for instance, have a memory image, an image of imagination, an hallucination, or the idea of justice arise; when it does, it occupies the central area while the other parts of that state of consciousness occupy the margin or obscure section. A lecturer preparing an outline of an address may be oblivious

of friends who pass; a manufacturer may scarcely notice the work of the dentist who repairs a tooth, for meanwhile he is planning a new factory. Sensory and imaginal clearness are commonplace occurrences in the world of daily experience.

Characteristics of the clear level. Let us note, first, the height or degree of clearness of the clear level. We have referred to the clear level as standing out in relief from the obscure level. What is the height or degree of clearness of this area of the field of consciousness? No definite answer can be given, for the degree of clearness varies with different individuals and with the same person under different conditions. With the feeble minded the clear area is perhaps never very high; with the genius it may be exceedingly clear. There are superior and highly disciplined minds which may become so attracted by a book that a nearby conversation or other forms of disturbance hardly exist. Such persons, as some absent-minded professors, may forget their hats, fail to put on their shoes before greeting guests, or unawares put one pair of overshoes on over another pair. Such absent-mindedness is in reality evidence of the presence of mind; it certainly is proof of the existence of a highly clear level, such as almost eliminates other parts of the field of consciousness. In hypnosis, the subject's field of consciousness is reduced so nearly to one object of thought that the clear level is very clear, while the obscure level is almost nonexistent; with marginal distractions, so to speak, removed, the stimulus object or the idea has the opportunity to appear with maximum vividness. In any event, when vividness increases, intensity seems likewise to increase.

The range of the clear level. As has been said, only one state of consciousness exists at a given moment. This

single state of consciousness may be simple or complex. The attentive consciousness may therefore be complex, yet it is one state having two levels. How many parts may be experienced clearly, and so constitute the clear level? One's attention may shift so quickly and one may count or estimate so swiftly that a condition of mind which one believes is only



C. H. Staeling Co.

Fig. 83.—Whipple's Portable Tachistoscope.

a single state of consciousness or attention is in reality inclusive of several states of attention. Therefore, the observations one makes of a given sensory field, in his efforts to determine the contents or the range of the clear level, must be made under conditions which would prevent any shifting of attention and prohibit counting different parts of the clear level. In vision this control can be had by use of a tachistoscope, an instrument which exposes the visual stimulus for only a small fraction of a second, thus giving no time for eye movement or for a critical examination of the field. The

stimulus card contains either small dots, or numerals, or letters of the alphabet arranged in haphazard order or several two-, three-, or four-letter words. If, for instance, cards containing dots are used in a given experiment, the observer reports the number of dots that he saw clearly. Altogether several hundred exposures are made of various stimulus cards; the records of reports are then canvassed, and the upper limit of clearness determined. Although there is not universal agreement on this point, it may be said that, with an experienced observer who has become accustomed to the apparatus and the experimental technique, the maximum range is six dots—that is, only six dots are seen clearly—while the others are vaguely and obscurely seen. Numerals, letters, and short words, because of their size and structure, are not so easily apprehended, so with them the maximum range is about four. In this connection it should be noted that a short word is observed as a unit, and not as a series of letters; the whole word is one impression. This tendency to apprehend a word as a unit shows why a child can learn short words as easily as he can learn the individual letters of the alphabet.

In efforts to discover the range of attention in the field of touch, several pressure spots, in close proximity to each other, are stimulated simultaneously. Again, the observer is asked to report the number that are clear in consciousness. Irrespective of whether ten or fifty pressure spots are stimulated, a maximum of six can be perceived clearly. The Braille alphabet for the blind, although not devised from psychological experiments, is based on the principle of the maximum range of tactual clearness. For the most part the letters, which consist of raised points, have only four points or less,

and are thus easily within the maximum limit of six pressure impressions. If a letter contained more than six points, confusion would occur, and it would be necessary for the reader to pause and count. Since the raised points which compose the letters are well within the upper limit, the reader does not have to count them; the letter is experienced as a unit the instant it is touched, just as in vision a short word or a very familiar word is immediately apprehended.

In audition the maximum range is also six impressions, or units of experience. In audition, the stimuli must of necessity be presented in immediate sequence. A metronome is one of the most convenient instruments for presenting successive auditory stimuli; the sounds are weak yet distinct, they are uniform in intensity, and the rate per minute can be controlled. The observer must be cautioned and trained not to count the beats; he must merely listen, to let his attention be attracted to the successive sounds only, and to forestall any tendency to count or estimate the number heard. If the metronome is set at a rate of about 15 beats per minute, the trained observer will be able to discover a maximum of six beats in the clear level. A larger number breaks up, falls apart, and causes confusion. If the rate is increased slowly, it will be discovered that the beats tend to fall into groups of two, three, four, and five; it is as if the two or more beats that compose the unit fall into a group which becomes one psychological impression. Rhythm enters into the experience, causing an accent to fall on the last number of the unit of two or more beats. Listen, for instance, to the ticking of a clock, and note how the fourth tick seems to be accented; it is as if that sound has greater physical intensity than the preceding three sounds. So, as the rate of the metronome

is increased, there appears the tendency of the strokes to fall into units; each unit is a psychological impression; as many as six of these units, a total of 36 beats, may be in the clear level. Some authors report a larger number. This is no violation of the rule that six is the maximum number in the clear level, for these units of sounds are similar to words taken each as a single impression.

One must not gain the idea that the range of the clear level of consciousness is merely a matter restricted to laboratory conditions; it obtains widely, if not constantly, in the sphere of everyday experience. It will be remembered that the memory span is about 7 syllables; a larger number causes confusion. A line of poetry contains at most only six feet; a larger number causes the line to tend to fall to pieces and brings confusion. Likewise, stanzas usually consist of only four lines. Moreover, a musical phrase cannot exceed six measures without grave risk of falling apart. There is something inherent in mind that permits clearness within the limits specified, and which tends to prohibit clearness and unity when those limits are exceeded.

The duration of clearness. In the course of ordinary daily experiences, one's attention fluctuates rapidly. One object of thought claims attention, then another and another in almost endless succession. It is now a flash of lightning, then the tinkle of the telephone bell, the crash of thunder, the rush of wind, the patter of rain, the roar of the car, the voice of a friend, the imagery of trees, and so on. Our problem here will, therefore, have to be restricted to the determination of the maximum duration of one state of the attentive consciousness. How long can one clear level remain clear without fluctuation?

Earlier experiments seemed to show that the clear level would fluctuate, that is, that attention would shift, at least every three seconds. In this work minimal sensory stimuli were used. For instance, the faintest visible gray circle on a rapidly revolved white Masson disk was fixated, and the observer pressed a key to indicate when the circle became obscure. In audition, the observer listened to a very weak tone, or to the slight continuous noise from a tiny stream of sand, and here, too, pressed a key to indicate each time the sound became very vague or vanished. In touch, faint pressure stimuli were employed. In each case the experience was so weak as to cause it to become almost imperceptible or to vanish from consciousness when it became weaker or when attention fluctuated. Observers usually indicated that shifts of clearness occurred about every three seconds or less. But objections to these results were made on the ground that the variations may have been caused by adaptation, by variations in accommodation, by adjustment of the tensor tympani of the middle ear, and by other peripheral factors. Elimination of the muscles controlling accommodation and of the tensor tympani did not stop fluctuation. Adaptation in vision probably accounts for shifts there, but in audition no adequate explanation has been offered. In touch, weak sensations do not fluctuate as they do in vision and audition. Here adaptation is relatively slow for some sensory experiences. The sensory experiences were reported as remaining constantly clear for about three minutes. It now appears that, if ideal conditions could be provided, that is, if all distractions were eliminated and a reasonably intense stimulus was used, the clear level might remain clear for ten minutes or even for an hour. Under ordinary circumstances, how-

ever, the clear level will likely be maintained steadily for a few seconds only.

The obscure level. The obscure level reveals very little of its nature or its contents to us. It exists as a vague, indefinite, obscure marginal section of the state of consciousness. It diminishes in clearness as the clear level becomes more vivid; as the clear level rises, the obscure level sinks into the background. Although this vague section plays an important part in directing one's movements, it seems to leave very little impression in one's memory. One avoids some obstruction on the walk, speaks to a colleague, turns in at the doorway, and climbs the stairs; one even drives along the highway and through crowded familiar streets; but one is able to recall almost no part of the walk or drive. At late evening one adjusts the thermostat, locks the front door, turns off the light in the study, and goes to bed; when, later on, he is asked about the heat, the door, or the light, he cannot recall whether or not he attended to any of them, for they were vaguely in the fringe of consciousness and left no impression adequate to satisfactory recall. To understand how weak and unclear such records are, try to recall the license number of your car, the type of numerals on the dial of your watch, whether or not the second hand completely obscures the numeral 6 on the dial, how many columns there are at the entrance to the library, the number of steps at the entrance to this building, and when you entered the door to the room in which you now find yourself. The clear level is the area of impression; the obscure level is too vague to etch itself upon memory.

Types of attention. We have seen something of the nature of the pattern or configuration of the attentive con-

sciousness. That pattern holds in every case of attention. There are, nevertheless, genetic aspects of attention which should be considered. For instance, one knows that in some instances one is spontaneously attracted by some object of thought, while under other circumstances one falters and wavers between two or more attractions. A symphony concert, a friend, or a good ball game claims one's attention without any effort. An assignment in Livy proves to be difficult, a theatrical performance promises to be fascinating; consequently one's mind fluctuates back and forth between the Latin text and the theater. What is the nature of such variations in attention? Is there some force at work within mind itself which operates under some conditions and does not operate under others? Is attention in one instance voluntary, and in another instance involuntary? We have said that science knows nothing of a separate faculty which directs mind; let us, then, turn to conditions of attention itself in an effort to discover its genetic characteristics. The old classification of attention as voluntary, involuntary, and nonvoluntary we shall discard for that of attention as primary, secondary, and derived primary, for this latter classification does indicate the genetic characteristics of attention.

Primary attention. Primary attention occurs when some object of thought forces itself into consciousness without any effort on one's part and without one having the power to prevent it. It simply breaks upon consciousness and demands recognition. For instance, one feels a sharp pain, hears the crack of a nearby revolver, sees the flash of lightning, and hears the locomotive whistle, not because one

wishes or plans to do so, but because those intense stimuli force themselves into consciousness.

There are many mechanical factors associated with objects of thought which, other things being equal, provoke primary attention. Let us examine some of them.

1. Intensity. Both intrinsically intense and relatively intense stimuli become clear. A shrill sound, an intense color, a sharp pain, a pungent odor, and a strong bitter taste will force themselves upon consciousness. The experiencing person has for the most part no choice in the matter. Then, too, the stimulus which is relatively most intense becomes clear. Expose momentarily a group of black dots, having one red dot in their midst; the red will be clear. Present a group of black dots, having one dot a more deeply saturated black than the others; the more deeply saturated black dot will be clear. Likewise, in other sense fields the relatively more intense stimuli claim attention.

2. Size. The largest object of a given class usually attracts attention. In a city, the tallest building; on the North River, the Leviathan; at the zoo, the giant python; on the street, the man eight feet tall—all seem to force themselves into consciousness more effectively than do the thousand normal-sized objects.

3. Suddenness. Sudden stimuli seem to break through to clearness. A sudden tone or an explosive noise, a flash of light, or a stab of pain seems to penetrate more effectively than do most of the continuous stimuli of the same order and intensity. It is as if the organism responds more effectively to a shock.

4. Repetition. Relatively weak stimuli, when repeated in rapid succession, seem to increase in intensity and break into the clear level. It is as if the strength of the nervous impulses becomes cumulative. Business houses attach sound devices to windows and use intermittent lights in order to attract attention.

5. Novelty. The unusual, strange, or bizarre object attracts. The peculiar bird having an enormous bill, the strange animals at a circus, the human freaks in side shows, and the cartoons used in advertisements and by illustrators—all such are examples of the capacity of the novel object to attract attention.

6. Position. Experimental work on attention, when the conditions of observation are under control, shows that objects in the lower left-hand section of the visual field attract first. Artists often provide for this tendency by subtly inserting lines of light and color which lead from this area to the main theme of the work.

7. Movement. A moving object in the field of vision, audition, or touch takes precedence over almost all other factors in its capacity to attract attention. A bird flying across the garden attracts one for the time more than do the trees and shrubs, while an insect crawling over the skin is more powerful as an attraction than all the wide areas of uniform pressure from the ground, the chair, and one's clothing.

8. Congruity. In general, one's mind seems to be prepared to respond to certain stimuli rather than to some others. Here, like tends to attract like; that is, objects in one's physical environment attract one, provided the individual's training has included such objects of thought. Thus, rock

formations attract the geologist, birds fascinate the ornithologist, good soil interests the planter, and a library charms the book lover.

Such mechanical aids to the arousal of primary attention, each one perhaps much more involved than the foregoing simple statements seem to implicate, play an important rôle in the development of the attentive consciousness. We shall return to congruity later.

Secondary attention. Who has not suffered the strain of having his attention shift from one object of thought to another when his interest should be devoted to a serious and immediate problem? One is often torn between conflicting or rival objects of thought. Under such conditions one is restless, wrinkles one's brow, perhaps walks the floor, feels fatigue, and accomplishes very little. This condition of fluctuation of attention is called secondary attention. Let us take an old hypothetical case by way of illustration: One has an animal which has an eye on one side of his head and an ear on the other side; provide a strong light on the side on which the eye occurs, and a loud horn on the side where the ear is located; then alternately sound the horn and flash the light. The creature will be attracted first to the horn and then to the light, and will alternate between the two until he becomes exhausted. One wavers in this manner when one is attracted by two or more objects of thought. One feels strain and suffers fatigue because of the constant changes in one's nervous and general bodily reactions, since under such conditions no one mode of adjustment is sufficient. For example, watch an unprepared student on examination, and note how he squirms in his chair, chews his pencil, looks at the walls, frowns, and finally leaves the room exhausted.

Note your bodily changes as you undertake to prepare a difficult assignment in higher mathematics, especially if a ball game is in progress, a garrulous visitor is with you, or jazz comes from a radio in an adjoining room. The conflicts and strains become almost unbearable. Under such circumstances, no appreciable progress at one's work is made. Psychologically, there is a great amount of truth in the story of the donkey who, with a bale of hay on each side of him, fluctuated between the two until he starved; and, in this connection, the statement that mental work is a waste of time is quite suggestive.

Derived primary attention. This is a condition of primary attention attained after one has passed through a condition of secondary attention. One of the two or more objects of thought now claims one's attention and has become sensorily or imaginally clear. At the same time, bodily adjustments occur and the state of conflict ceases. One becomes absorbed by the Plato, the novel, the mathematics, or the idea of the symphony concert. The body is relaxed, the feeling of strain has subsided, and mental processes flow smoothly. It is a state of primary attention without the shock that may attend the appearance of intense or sudden stimuli.

Accommodation. Casual observation and scientific investigations reveal the existence of numerous adjustments of body and mind when a state of attention occurs. What are some of these changes?

Bodily changes. It has already been noted that bodily changes accompany attention. The extent and influence of such changes cannot yet be fully shown. One must be content at this time to list certain changes that may be observed.

When one is strongly attracted by some object of thought, one's body may lean forward, the eyes may become fixed on the object, respiration becomes shallower, the rate and strength of heart action change, and muscles become tense. No fixed rule covering changes can now be made, for there exists such a diversity of circumstances and so much variation in the physiology and the training of different people. Bodily accommodation does occur, and it tends generally to facilitate attention.

Psychological accommodation. In addition to the formation of the pattern of the attentive consciousness itself, there are general adjustments of the mind which must be noted. For example, the sounds from my radio seem to come from above the table at my left until I discover that someone has placed the loud speaker on the floor beneath the table; the experience concerned with the origin of the sound instantly shifts to the instrument when the change in the position of the instrument is discovered. At the movie one hears words as coming from characters on the screen, when in fact the sounds may come from an instrument placed several feet to one side of the screen. There occur such mental adjustments as may be necessary to shift the sounds to their supposed origin. This accommodation is possible because the images on the screen are in the clear level of consciousness, while the source of the sounds, if not the sounds themselves, is in the obscure level. This type of mental accommodation can easily be demonstrated by means of a large clock dial having large numerals and around which revolves one large clock hand. A bell is adjusted so that it will ring when the hand passes a certain point on the dial. The observer is asked to attend to the sound of the bell and to specify where

the pointer is when the bell rings. Attention may consequently become so attracted to the bell that the observer may report hearing the bell far ahead of the point at which it actually rings. If, on the other hand, the observer fixates the dial and the clock hand and lets the bell fall into the obscure level of consciousness, the place where the bell is heard may

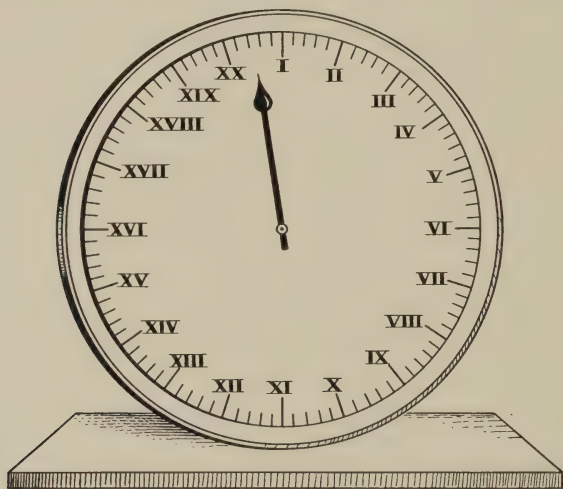


Fig. 84.—Accommodation Clock.

move forward several degrees on the scale if he lets his attention become attracted to that place. The mind simply accommodates the sound to the place, just as one hears a tone coming from the object which appears to produce it.

The observation may also be made with the use of an ordinary bell metronome. A pointer, attached to the pendulum, swings back and forth along a scale outline on a background of cardboard. The bell is set to ring as the pointer passes a given place on the scale. If the observer is attracted by the scale and lets the bell fall into the margin of conscious-

ness, the position at which the bell is heard may be shifted several degrees. As with the other type of apparatus, and in everyday experience, the sound seems to originate at the place at which the observer expects it to occur.

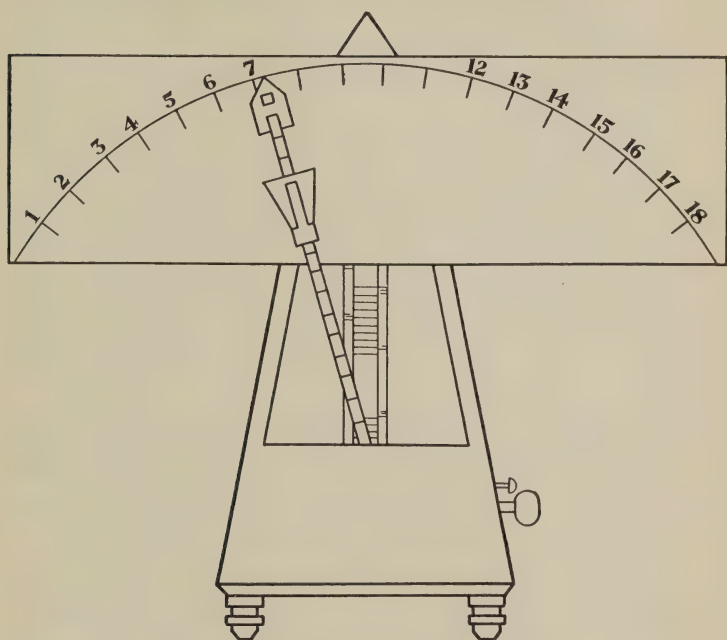


Fig. 85.—Accommodation Scale.

The accommodation that occurs in attention consists, then, of both mental and bodily adjustments. All the factors involved cannot now be listed, nor can a complete statement concerning the correlation of the mental and bodily processes be made. There is, however, exhibited in accommodation, evidence of the intimate relation between body and mind. Let us turn to some plain illustrations. Everyone has noticed the differences in the facial expression, the position of

the body, and the respiration of one who is utterly indifferent. Some of us know that the act of writing and sitting upright in one's chair in the classroom are aids in hearing the lecture, while idleness and a careless posture encourage indifference. Moreover, one type of process facilitates or inhibits another process. The knee jerk occurs more easily when one clasps the hands together tightly; a sneeze may occur more quickly when one thinks of the sensory experiences around one's nostrils; the sneeze may be stopped by pressing on the upper lip, by rubbing the palms of the hands vigorously, or by suddenly having one's attention attracted strongly to some other object of thought. Some thought processes, therefore, strengthen other thought processes and bodily activities, while some bodily changes enhance thought.

Conversely, there are also mental processes and physiological responses which inhibit other activities. In brief, mental and bodily accommodation usually, at the same moment, facilitate in one direction and inhibit in other directions. It is probably in such conditions that one may discover the explanation of the clear and the obscure levels of the attentive consciousness. When one is attracted strongly by some object of thought, that object is very clear and the marginal areas are vague; coincidentally, both the mind and its bodily correlates have converged upon the object so that all other conditions of the environment are all but eliminated. Moreover, the fatigue which may occur during a prolonged condition of secondary attention may be a result of the frequent shifting of the neuromuscular correlates of the fluctuations of consciousness. Again, for instance, watch the unprepared student on examination, or a highly embarrassed individual

on some formal occasion. The readjustments produce not only discomfort; they bring about a measure of exhaustion.

Education and attention. It has been pointed out that congruity is a determining factor in attention. When the data and associative tendencies of mind are such as correspond to some part of one's environment, that particular section of one's surroundings is likely to claim one's attention. Moreover, one's interests in some environmental conditions, or in one's ideas, are contingent upon the similarity of one's mental contents and one's associative bonds on the one hand and the objects of interest on the other. Now, this relation is not one suddenly or spontaneously arrived at; it is a result of discipline of the mind and its bodily correlates, a discipline which, with an adult, has extended over many years and has involved both formal and informal training. In this way one's mental data are acquired, one's associative bonds established, and one's bodily habits formed. One thus becomes ready to be attracted by or to become interested in some one phase rather than another part of the total environment.

With the possible exception of the intense stimuli which force themselves into consciousness and over which one has little if any control, it may safely be said that one cannot be interested in something about which he has no knowledge. For instance, hand one a page of Chinese characters, a textbook of neuropathology, or the score of a Wagnerian opera; he will be interested only to the extent that his training permits him to understand the Chinese language, the pathology of the nervous system, or operatic music. Watch the geologist as he is held by some rock stratum, the archeologist as he examines a piece of pottery, the bibliophile when he finds

a rare volume, or the botanist when he discovers a rare specimen. The fascination occurs because of the fact that the person's training has prepared him to respond. From one point of view, one is attracted because, through experience, one possesses something which can be attracted. One cannot think in or with a mental vacuum; neither can an object of thought attract a psychological nothing. Interest is, therefore, generally dependent upon the nature of the object of thought and the condition of the mind itself. Although mind may be regarded as an active principle which is not restricted in its activities to modes of physical behavior, it cannot exceed in its functions the data which it possesses. As a stream of conscious processes, the mind may flow in this or that direction, but the course which the mental stream follows is governed by psychological laws and one's conscious processes; one's mind is composed of mental data, and these data, like a stream, must follow certain courses.

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CHAPTER XVI

Emotion

AN EMOTIONAL state is vastly complex. One has only to make a cursory examination of a condition of sorrow, rage, or fear to discover the wide range of the psychological and physiological components of the emotion. Take, for instance, a case of momentary terror. Suppose a reckless driver turns his car directly toward yours; a head-on collision seems imminent. The cars pass, however, without damage. But one hears the screech of brakes and tires; one's muscles become taut and then feel limp; cold perspiration stands out on one's face; respiration stops for a moment; the heart becomes accelerated; cold chills move along the spine; visual imagery of the highway, cars, and the driver appears; there are suppressed vocal comments, or screams perhaps are uttered; and the entire experience is definitely colored by unpleasantness. Many other things may appear as a part of the total complex experience, but these are enough to show something of the scope of an emotional condition. In a critical treatment of emotion, the problem consists of making an analysis of a typical emotional state, in order to show the constituent parts and the rôle each part plays.

Right here one meets obstacles. There is no general agreement among psychologists, or between psychologists and physiologists, about the essential characteristics of emo-

tion. This lack of agreement is easily understood, for psychology has had insufficient time to make either a complete descriptive examination or a satisfactory organized study of the subject, as an emotion consists not only of complex psychological states but also of widespread bodily changes. Moreover, physiologists do not appear to be of one opinion about the location, the origin, or the nature of the nervous correlates of a given emotional condition. Withal, emotion seems definitely to have a nervous and glandular basis; in many respects it seems to be instinctive; it is, moreover, obviously psychological in its nature and influence. In the predicament which this emotional maze offers, one can give only a tentative outline of the essential characteristics of an emotion. It must be understood that no analysis is quite specifically applicable to any two emotional states; the differences in the nervous disposition and in the mental development of different people are too vast for any formula or stereotyped statement to apply generally.

Analysis of emotion. We shall, however, specify generally some indispensable parts of a typical emotional state of fear, anger, or rage, in lieu of more accurate, comprehensive, and satisfactory descriptive treatment which, it is hoped, will become available to us as experimental work progresses. As already implied, emotion is no mere psychological entity; nor is it a stable, predictable unity of body and mind. Then of what generally does it consist?

Sensory experience. An emotional state usually embodies a core of sensory experience. The sensory experience—colors, sounds, tastes, smells, and touches—usually starts the emotional complex. One has only to review one's experiences of anger or fear to discover how some auditory or visual

stimulus often served to touch off the emotional explosion. The sensory stimuli do not constitute the emotion, just as the electrical impulse which explodes a charge of dynamite is not the physical explosion; it merely sets off the charge. The same modes of sensory stimuli may be had almost constantly, but there must be some total set up, some psychophysiological keg of powder, ready to be exploded. The sensory stimulus itself may be mild or intense, simple or complex; a spark or a bolt of lightning may discharge dynamite. So, the weak sound caused by a mouse at night, a visual experience of red, a faint odor, or a weak pressure may be sufficient to provoke intense fear. The quality and intensity of the sensory stimuli are themselves not here important; what the stimuli ignite, as it were, is highly significant.

Imagery. We have discovered at least two general facts about images: they occur as of any sensory order, and they become associated with any perceptive experience. Emotion offers no exception with respect to images; here they usually appear in abundance. Suppose one hears a crash and a scream; instantly visual imagery of a wrecked car, the highway, the injured or dead passengers, a group of spectators, an ambulance, and so on may rush through consciousness. Again, suppose one is alone in a house at night and a noise is heard at a window; immediately imagery of a burglar, a weapon, the window, and the like may spring into consciousness. Illustrations to be found in the field of visual imagery are usually clearer than those to be had from other sense fields, but it must be remembered that imagery may also arise as from any other sensory order.

Now, imagery may play two rôles in an emotional experience. First, images, instead of sensory experience, may

touch off the emotion. Upon reflection, this fact becomes perfectly obvious. Who does not experience disgust, or anger, or sorrow when certain memories or memory images reappear? Who does not likewise experience pleasure when he recalls images of a friend or a symphony concert or a beautiful garden? There are recurrent images, the replicas of horrible visual observations, which frequently arise in consciousness and initiate unpleasant emotions. Even the imagery of dreams, deliria, and hallucinations is more often than not attended by pleasant or unpleasant, mild or violent emotionalism.

Second, imagery enriches the emotion by making it more complex or more meaningful. In general, the poverty or the wealth of associated experiences determines the degree of intensity of an emotion. This is not always true, for there may be violent emotional expressions exhibited by those who probably have a limited store of mental images; even lower animals exhibit evidences of violent emotions. Nevertheless, with the normal human being, the rise of images enhances an emotional state, just as imagery may make a meaning richer than it could otherwise be. A very young child may experience emotion, but it is likely that, with its very limited store of images, the emotion consists largely of sensory experiences and feeling, and that it cannot therefore have the scope or richness of an emotional state experienced by an adult.

It may also be said that imagery prolongs an emotion. If, when an emotion appears, a stream of imagery continues, it is likely that the emotion will last as long as the flow of images persists. If one's images of a burglar in some part of the house persist, or if images of some individual who

acted discourteously continue to arise, the emotion will be prolonged; when they cease, the emotion very likely will subside or vanish.

Affection. Since 1884, when William James advanced the theory that emotion consists of sensory experiences, a generally accepted definition of emotion has not been formulated. There is diversity of opinion with reference both to the nature of affection and to the part, if any, it plays in emotions. In this present study, however, it is assumed that affection is an indispensable part of any emotion. Emotion is regarded as a total psychophysiological situation, a complex experience consisting of sensory, imaginal, and affective components with many physiological correlates. Without the presence of the affective process a complex experience simply would not be emotional. One may have highly involved perceptions attended by widespread bodily changes, and at the same time the perceptions cannot be called emotional simply because the affective process is not present. Such a condition would be without feeling; it would be colorless, nonaffective. Affection, when present in a complex state of mind, gives the color or feeling to the experience. In the case of emotion, the experience, we assume, becomes emotional immediately when the affective increment appears. Now, as was indicated in our study of the affective process as an element, there are two affective qualities, namely, pleasantness and unpleasantness. These qualities are unique and incompatible. When, therefore, affection occurs in conjunction with the sensory and the imaginal components of emotion, the total experience becomes pleasant or unpleasant; it is not only richer as a perceptive experience, if the necessary sensory and imaginal constituents are present, but the affec-

tive process also makes the total experience emotional. The affective increment may, therefore, be regarded as the core of feeling indispensable to the emotional complex.

Secondary sensations. As we have already discovered, an emotion is perceptive. The meaning associated with emotion may be vague and restricted, or clear and rich. In either case secondary sensations accrue, just as they appeared as an essential part of meaning. In emotion, these secondary sensations may appear from various sense fields; the majority of them, however, as one would expect, arise from the field of touch. For instance, various changes occur in respiration, heart action, the digestive tract, the skin, the facial muscles, the muscles of locomotion and other gross bodily movements, the lachrymal glands, the throat muscles, and so on. William James likened the body to a very delicate sounding board which vibrates sympathetically with the sensory or perceptive components, thus making the total experience much more complex and intense than the initial exciting sensory or imaginal experience. One who has experienced sudden fright, caused at night by the rattle of paper at one's feet or by stepping on a snake, knows of the cold chills along the spine, the hair standing on end, the pounding of the heart, the respiratory inhibition, and perhaps the violent muscular responses.

Of course not all these changes, from which secondary sensations arise, are necessary to a given emotional experience, but some secondary sensations are indispensable. It would probably be impossible for a completely anaesthetized individual or a completely desensitized animal to experience emotion. Decorticated cats and spinal dogs—that is, cats from which the cerebral cortex has been removed and dogs

in which the spinal cord has been cut at the central end—may exhibit evidence of emotion, but the former have the cord and lower brain areas intact, while with the latter the brain and some sensorimotor areas remain untouched by the operation. Whether bodily changes are overt or not, in all probability they occur and furnish the stimulation necessary to the arousal of secondary sensations.

If our general analysis of an emotion is correct, the experience is not elementary and stable, but complex and variable. Like perception, no two emotional states may be identical, and various changes in its structure and intensity may occur during the temporal progress or course of the same emotion. The analysis into sensory, imaginal, and affective processes must be regarded, therefore, as an outline of the typical experiences that constitute an emotion, and not as a statement showing the particular processes that compose any one emotional state.

Bodily changes associated with emotion. In an earlier section it was indicated that a large number of bodily changes occur during the course of an emotion, and that from such changes arise sensory stimuli which accrue to the core. These changes are so widespread and significant that they warrant tabulation here. Again, the present list is typical only. No final or satisfactory classification of different emotions can at this time be made, and no general group of bodily changes appears to be peculiar to any one type of emotion. For instance, one may weep for joy or sorrow, run in anger or in fear, and laugh for pleasure or in the hysteria of horror. The significant fact here is that of the changes themselves, and not the effort to associate certain changes with anger, fear, joy, or rage, or even more generally with

pleasant or unpleasant emotional states. What are some of these bodily concomitants of emotion?

Respiration. The normal rate of respiration is about 17 times a minute; the rate may vary from 13 to 25 times a minute during health, while abnormal conditions may cause wide variations from these limits. The respiratory movements, including inspiration and expiration, are produced by the intercostal and the abdominal muscles. The amount

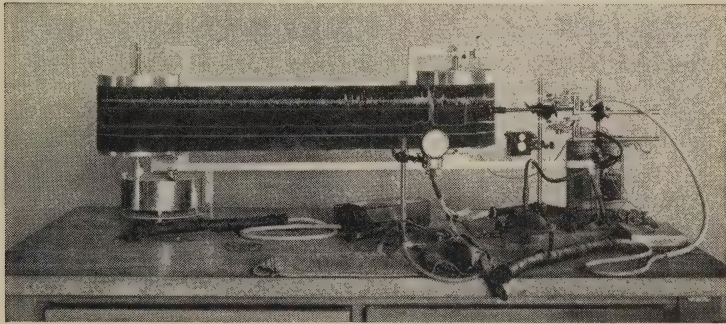


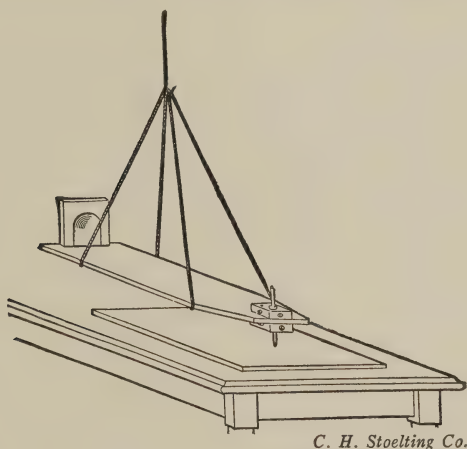
Fig. 86.—Apparatus for Recording Respiratory and Circulatory Changes.

of air inhaled and exhaled in an act of respiration is about 500 cm^3 . Respiration is, for the most part, controlled reflexly; the reflex impulse is started by excess accumulation of carbon dioxide in the venous blood in the alveolar region of the lungs. By means of a pneumograph and a spirometer, the rate and depth of respiration may be recorded. Generally, during a pleasant emotional state the rate of breathing is increased, and the depth or volume of inspiration is decreased; while during an unpleasant emotion the rate is decreased and the volume of air inhaled is increased. These statements are subject to modification, for the amount

of carbon dioxide formed in the body may be increased by bodily activity and the respiratory rate and depth consequently increased. Any appreciable increase of bodily activity would, therefore, as a result of the waste products formed by the physical exertion, cause a change in the rate of breathing, whether the emotional state is one of fear or joy. The changes in the respiratory rate set up sensory experiences in the region of the chest and the abdomen, and around the nostrils and other air passages. The sensory experiences are particularly conspicuous when breathing is momentarily inhibited or becomes excessive in rate or depth. Of course such respiratory changes may occur when no emotional state exists, but when they occur in connection with an emotion they add to the total experience and thus enrich it.

Vasomotor changes. The rate of the heart beat and of the pulse is approximately 70 to 72 beats a minute. At this normal rate vasomotor activity is usually imperceptible except when one makes special investigation by the use of a stethoscope or by feeling the pulse at the radial artery in the wrist. With a sphygmograph both the rate and the height of the pulse can easily be measured. In the case of a pleasant emotional state, the rate of the pulse is slightly decreased, and the height increased; during an unpleasant emotion, the rate is increased, and the height decreased. This statement must also be qualified; for physical exertion, fright, or nervousness may cause both an acceleration of the rate of heart action and an increase in strength of the beat. Here, too, the important matter is the fact of the changes and the consequent sensory stimuli which may form a part of an emotional state.

Direction of bodily movements. Suppose the hand and arm are placed on an automatograph, an instrument which consists of a board suspended from the ceiling which has loosely attached to one end a stylus that records on a large piece of smoked glass any movements of the arm. The observer, who is blindfolded, is then given, first, a stimulus which arouses a pleasant emotion, and then, later, a stimulus



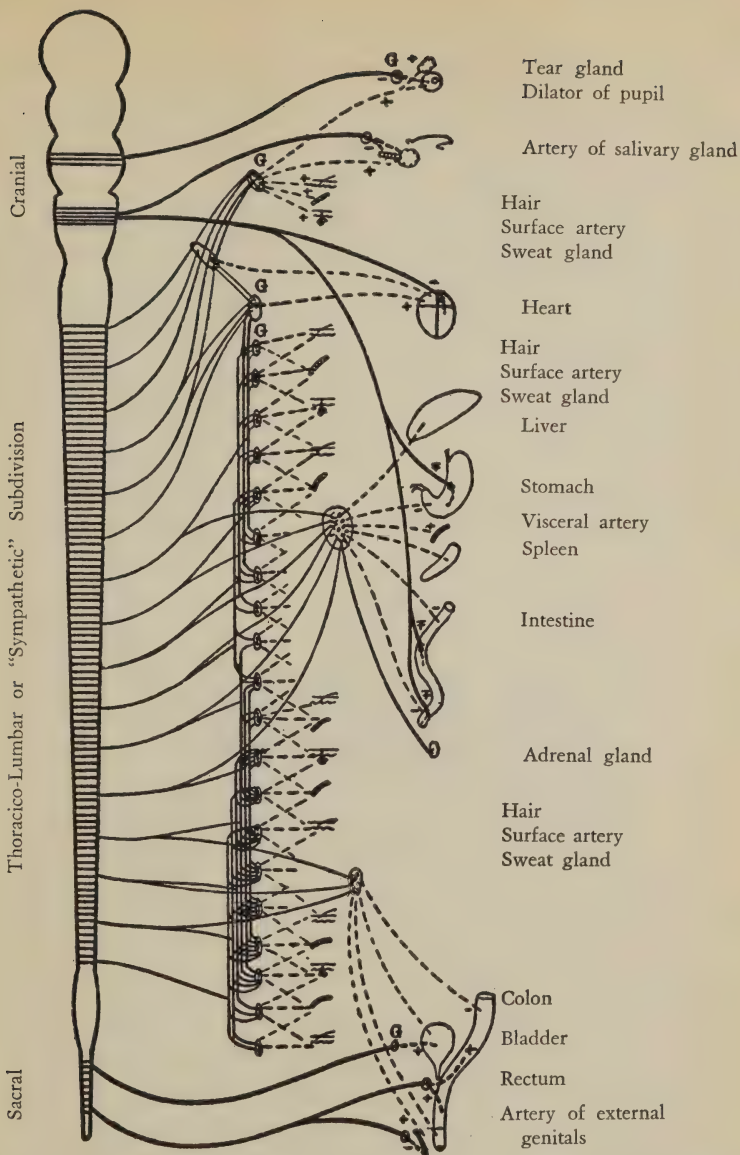
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Fig. 87.—Titchener's Automatograph.

which provokes an unpleasant emotion. If many records are thus made, what generally are the results? The arm tends to move in the direction of the supposed source of the pleasant emotion, and it tends to move away from the supposed location of the cause of the unpleasant emotion. If the objects are beyond reach and apparently nothing can be gained by movement, a stimulus which arouses a pleasant emotion may cause muscular relaxation, while a stimulus which provokes an unpleasant emotion causes muscular tension. Of course, as has been pointed out, emotion is per-

ceptive; and perception may imply actions other than the so-called involuntary movements. Of course, therefore, one does not always move toward the pleasant object and away from the unpleasant object. One may strike a mosquito or approach an enemy, and one may turn from pleasant objects because the situation so demands; the criterion in perception is to be found in habitual responses or judgments. In purely involuntary movement, however, one moves toward what he likes if it appears possible to reach it, and away from what he dislikes. Such movements arouse sensory experiences which accrue to the emotional core.

Changes in the blood. Three changes that affect the general tone of the body occur in the blood stream when an emotional state which implies action or strenuous exertion arises. First, in the case of fear and rage, an excessive amount of adrenin is given off into the blood. Adrenin is a powerful stimulant secreted by the medulla area of the adrenals, which are members of the endocrine system of glands. Second, as the result of an influence of adrenin, the liver releases additional glycogen which is carried by the blood to the muscles. Third, as another effect of adrenin, the spleen releases more red corpuscles. Moreover, fatigue is decreased, the tonicity of muscles is improved, the bronchioles become dilated, and the blood clots more quickly in case of a wound. Cannon, who has made such discoveries, insists that such organic changes, almost if not all of which result from the excess secretion of adrenin, are a preparation of the organism for combat or some other mode of defense. Irrespective of the purpose, such changes do occur, and altogether they greatly influence the emotional condition. The injection of adrenin seems not to produce an



After Cannon

Fig. 88.—Diagrammatic Representation of the Autonomic Division of the Nervous System.

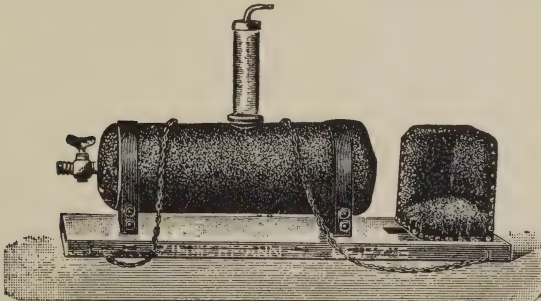
emotion; it does, however, produce physiological conditions which appear to serve as a basis of emotional growth and expression in case something should touch off the emotion.

Thyroxin. The thyroid gland, located in front of, and on either side of, the trachea, is another member of the endocrine system which may influence the development of emotions. In hypothyroidism, a condition in which the patient suffers from a deficiency of thyroxin, the body seems to be subnormal in its responsiveness to stimuli. Congenital hypothyroidism causes cretinism which includes mental subnormality and slowness in reaction time, as well as numerous bodily defects. Hyperthyroidism, a condition in which the patient suffers from excessive secretion of thyroxin, whether in mild form or as exophthalmic goitre, usually causes the patient to be very sensitive and irritable. Such an individual is, therefore, more susceptible to emotional states, particularly of the unpleasant types. The patient is, of course, unaware directly of thyroxin itself, but a diagnostician or an expert observer may with relative ease discover symptoms of a deficiency or an excess secretion of this hormone. Mental irritability is one common symptom.

Secretion of digestive fluids. Emotional states facilitate and inhibit the flow of saliva and the gastric juices. Extensive observations in this relation have been made in connection with man and the lower animals. Direct observations, through fistulous openings into the stomach, have been made to note the flow of gastric juices during pleasant and unpleasant emotional states. Stomach pumps also have been employed to remove the secretions formed during a given period. Salivary secretions are, of course, easily measured. Results show that pleasant emotions increase the flow

of saliva and gastric juices, and that unpleasant emotions, as anger, disgust, and sorrow, check or stop the process of secretion. It may be said, therefore, that pleasant emotional states facilitate digestion and cause a general feeling of well-being, whereas anger or sorrow may prevent normal digestion and cause a feeling of heaviness and discomfort. It is also believed by some that anger causes saliva to become more acid, and therefore produces abnormal taste experiences. Such changes obviously affect one mentally and thus may affect the complexity, the intensity, and the duration of an emotional state.

Size of the limbs. With the use of a plethysmograph, changes in the volume of some parts of the body can be



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Fig. 89.—Lehmann's Plethysmograph. (This instrument is used to detect changes in the size of the hand and forearm.)

recorded. This instrument is a large container in which the hand and forearm, or the foot and lower part of the leg, are inserted. The vessel is filled with water, warmed to skin temperature, so that the water extends up to a given level in a small graduated glass tube. Any change in the volume of the limb will cause the level of the water in the tube to rise or fall. The tube may be attached to a tambour so that a

record of any changes will be made on smoked paper placed on a kymograph. Pleasant emotional states cause a slight increase in the hand and arm, and in the foot and leg. An instrument designed to fit around the skull is reported to show a slight increase in the volume of the head when the subject is pleased with himself. On the other hand, unpleasant emotional states produce a slight decrease in the volume of a limb. It appears that vasomotor adjustment causes more blood to go to a given part of the body when a stimulus arouses a condition of pleasure, and less blood to enter that area when the stimulus provokes a state of displeasure. The changes in volume are, at most, very small, but they seem to indicate a mode of adjustment which provides some amount of sensory increment and which thus modifies one's attitude during a state of emotion.

Other changes. In addition to the bodily changes already listed, there are many other changes which may be observed. Facial expression becomes so pronounced and so definitely associated with emotions that it is a good index to types of emotions. Sorrow, disgust, horror, surprise, hate, and joy may usually be detected with considerable ease. Changes associated with the forehead, the eyebrows, the eyelids, the nose, and the mouth are as effective as they are conspicuous. The lachrymal glands may function more or less profusely. The skin may become blanched from the constriction of the peripheral blood vessels, or red from the dilation of these vessels and the excess amount of blood in them. Cold sweat may appear. Cold chills may seem to move along the spine. At times the muscles of the scalp are involuntarily stimulated and the hair seems to stand on end. Muscular tone may be so modified that, in grief, one's body

is stooped and one's movements slow; or, in joy, one may be more erect and become more alert in one's movements. Some of these modes of expression seem to be innate, others seem to be learned or developed; all become more or less stereotyped reasonably early in life.

There are no exact patterns of bodily changes that correspond to a classification of emotion into love, hate, anger, fear, and so on. Some symptoms of a given type of emotion, as anger, may regularly appear with that emotion; nevertheless, no group of changes is common to anger, to fear, or to sorrow only. As has been stated elsewhere, emotion is perceptive, usually implies action, and is generally so complex that many types of bodily reactions may be involved. For instance, one may run for fear or for pleasure; weep from sorrow, anger, or joy; blush from shame, pleasure, or anger; have more adrenin secreted from terror, or from anger; experience cold chills from fright, from hearing great music, or from reading a poem. The real significance of these bodily changes is to be found in the fact that they are the source of a vast number of secondary sensations which form a part of the emotional complex.

The temporal course of emotion. Our descriptive analysis shows that emotion, with all its perceptive, ideational, affective, and physiological components, is very complex and runs a course temporally. What is the nature of this temporal course? As a rule, the emotion as such begins abruptly, and subsides gradually. The emotional consciousness as such, let us repeat, appears suddenly, and not slowly as some suggest. Of course sensory experience or perceptive experience may occur first in time, and even numerous bodily changes may appear and increase in intensity. But, as we

have said, an experience is not emotional until the affective process arises; and, since the affective process appears rather suddenly, so the total complex abruptly becomes an emotional consciousness. An emotion usually dies down gradually. The reason for this is obvious. The train of thought, such as occurs in joy, sorrow, anger, or fear, does not cease abruptly; the mind is aroused, and the associative bonds are usually so numerous as to make possible long sequences of images and ideas. Moreover, the number and scope of bodily changes are such as hardly make it possible for them to cease abruptly. The excess amount of adrenin, for example, cannot vanish instantly from the blood; nor can its excitation of the liver and other structures stop within a moment. Furthermore, vasomotor changes, respiratory disturbances, and fatigue tend to persist for a while. The time required for an emotion to disappear varies widely with the same individual and with different individuals. Some emotions are more intense, more serious, and more involved than others; one's condition of health and one's attitude at a given time may cause the duration of the emotion to be brief or long.

The James-Lange theory. In 1884, William James, and, in 1885, C. Lange, of Copenhagen, independently advanced the theory that reflex bodily changes follow immediately after the exciting stimulus, and that the emotion is one's feeling of these bodily changes. In other words, the various bodily changes are caused by the perception, and the sensory experiences are essentially the emotion. To use familiar illustrations, the theory implies that one is sad because one weeps, happy because one laughs, afraid because one runs; the bodily changes involved set up sensations which, in combination and relatively intense form, comprise the emo-

tion. The bodily changes do form such a conspicuous part of an emotional experience that one may be inclined to agree with James and Lange.

Two objections to the theory, however, are offered here. First, affection is indispensable to emotion; without this core of feeling, emotion as such cannot exist. The bodily changes that generally appear as a part of emotion may occur without the occurrence of emotional consciousness. One may run, fight, or, if one is an actor, laugh and weep and exhibit anger without experiencing emotion. Second, the same types of bodily changes occur with different types of emotions. As we pointed out in another section, one may weep for joy, in grief, or during anger; one may run through fright, for pleasure, or in rage; adrenin, glycogen, and red corpuscles are provided in larger quantities during fear or anger, and even in a pleasant struggle where keen rivalry exists. Many of the bodily changes are so common to various types of emotions that this fact alone seems to be a fatal objection to the James-Lange theory. It is perhaps much more nearly correct to regard emotion as consisting of sensory, imaginal, affective, perceptive, and ideational components, and then look to the biological organism for physiological correlates. This brings us to a discussion of the nervous system as a basis of emotional behavior.

The nervous correlates of emotion. The relation of emotion to the nervous system seems to be an intimate one. Very soon after birth the child expresses evidences of emotional behavior. As he grows older, the modes of emotional expression may become more stereotyped. It may also be noted that, as one grows from infancy to maturity, emotions seem to become more perceptive, that is, they seem

to be more meaningful and, in their occurrence, more intimately linked up with and directed by conscious interpretations. To state it in another way, the infant's emotional states, as fear and hunger reactions, seem to be organically or instinctively motivated, while the emotions of the adult may be controlled largely by meaning or ideation. Again, it may be suggested that emotions of the more organic type, as those related to combat and sex, are controlled chiefly by lower and more primitive sections of the brain, while emotions arising from ideation are intimately associated with the higher cortical areas.

Experiments performed upon dogs and cats throw some light on the problem. Hemisphereless dogs and cats, animals from which those areas of the cerebrum which appeared last in organic development had been removed, showed marked evidences of fury and rage. Mild or commonplace physical stimuli were sufficient to provoke excessive emotional responses. Decorticated cats likewise exhibited many different and pronounced bodily activities similar to those associated with rage. It appears, then, that bodily responses in rage may have their nervous origin in a part of the old brain. When the cerebral cortex is removed, it appears that rational control of emotion is also eliminated, and that under such a condition the so-called instinctive or animal impulses express themselves more freely. Thought, especially if it is of a higher and rational nature, seems to hold one's lower emotional urges in check; remove intelligent control and the governor is eliminated.

The sympathetic division of the nervous system must also be taken into consideration. The sympathetic system con-

sists of a chain of nerve ganglia extending along each side of the spinal column, and leading to the involuntary muscles. The system is associated with the heart, the liver, the stomach, the intestines, and other divisions of the viscera. During an emotional state the sympathetic system may facilitate activity in some internal organs and inhibit activity in others; the nature of a given emotion seems to determine the type of sympathetic control effected in that case. Withal, a delicate adjustment is maintained between the mind and the sympathetic system and between the sympathetic system and the viscera; an emotional state may, therefore, produce minute or gross disturbances of the viscera. There is, then, no wonder that so many changes in bodily activities occur in connection with mental disturbances, and that the psychological aspects of an emotion are influenced greatly by such neuromuscular activities.

The discipline of emotion. An examination of the ways in which one's emotional habits develop, and of the means of disciplining one's emotional life, may assist us in efforts to understand emotion. It has been seen that emotion consists of a pattern of various types of mental processes, accompanied by numerous organic changes. It was also suggested that so-called instinctive emotions may be restrained by thought processes correlated with the region of the higher cortical centers. Now, since emotion plays such a significant part in one's life, the question of the advisability and the means of training the emotions arises. Can emotions be disciplined properly? Should they be suppressed? Only one answer seems advisable. Since emotion is a part of one's mental life, just as definitely so as is reasoning, there should

be adequate training of one's emotional nature. How can such training be had? One must turn again to the nature of emotion to discover the answer.

In the first place, emotion is perceptive. With the normal child, youth, or adult, an emotion embraces a large amount of data that add meaning to the experience. These data have been acquired directly or indirectly through sensory experience. The nature of these data is largely dependent upon the environment in which they were acquired. The associations or meanings formed through the use of these data likewise depend largely upon one's environment, a fact which is tremendously significant. The first step, therefore, to be taken in training emotion is that of acquiring adequate mental data of, so to say, a high quality, and then seeing to it that proper meanings are formed of such data.

Second, emotion is affective. As stated elsewhere, the presence of the affective process makes the total experience an emotional consciousness. Now, how is it that some emotional states are consistently pleasant, while others are just as regularly unpleasant? It is in the answer to this question that one secret of the training of emotions may be found. Of course some sensory and perceptive experiences are of such quality, intensity, or meaning as will likely produce a pleasant emotion, while others just as readily provoke unpleasant emotions. Saturated colors, sweet tastes, smooth tones, and fruity odors tend to be pleasant, while faded colors, bitter tastes, shrill tones, and nauseous odors are usually unpleasant. Likewise, some meanings are more likely to develop pleasant emotions, while others seem more likely to produce an unpleasant emotion. With the exception, how-

ever, of a rather restricted field of experience in which one has very little control of one's feelings and emotions, the appearance of pleasantness and of unpleasantness in association with certain types of sensory experience and certain perceptions is primarily a matter of the formation of associational bonds. If a given perception is attended by the affective quality pleasantness today, tomorrow if that perception reappears it is likely to be pleasant also. The more numerous the repetitions of the association between the perception and the affective process the stronger the bond between them is likely to become.

Such associations may be formed directly or indirectly. One may dislike bad medicine because the taste is bitter; one may dislike coffee because one took the medicine in coffee; one may dislike the nurse because she prepared the drink; and one may dislike redheaded women generally because the nurse who prepared the offensive medicine had red hair. The variety of associative bonds established and available under such conditions is sufficient to make unpleasant emotions appear easily and habitually under such conditions. It is in this way that one's emotional habits become established. The variety, therefore, of different modes of training easily explains the wide range of human likes and dislikes. Think of different types of food enjoyed by different people; note the buildings in which people live, as well as their physical environment generally; observe how emotional behavior is employed from infancy to develop loyalty and hate; make a survey of the standards of beauty to be found in different parts of the world. It will be found that a given individual may be trained to enjoy or to dislike al-

most any perceptive or ideational mode of experience. One's affective attitude depends primarily upon the establishment of the associative bond which tends regularly to color the total experience with pleasantness or unpleasantness, as the case may be.

Third, the organic correlates of emotion tend to become habitual in their appearance along with the perceptive, the ideational, and the affective complexes. Let a given mode of bodily response occur in connection with an emotion, and later a similar emotion will tend to be accompanied by the same type of bodily responses. Let a child become afraid of the dark, cry, and require that a light be left burning in the nursery; then see what he will demand the next night. Permit a child to become terrified at some feathered animal, water, a high place, or a morbid death; the chances are that the delicate organic structure will be so modified by the strain or shock that it may never fully recover. The records of abnormal psychology are filled with reports of the persistence of such effects. The wholesome part of the picture is less graphic but just as significant. The normal organism, normally developed, is an invaluable asset to emotional control.

All considered, then, the training of emotions depends upon the nature of the contents of mind, the meanings established, the associative bonds related to the affective processes, and the discipline of the body. Their wholesome development and harmonious relations are highly to be desired. It should be remembered, however, that, since emotion is one of the most powerful forces related to human life, improper development and harmful habits of expression may easily wreck the individual.

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CHAPTER XVII

Action

MANY words, such as energy, force, and action, connote so much and suggest such a wide variety of interpretations that, frequently, restricted meanings of such terms must be employed in one's discussion of a particular subject. The word action thus has a large number of different meanings. Its application seems to be possible in almost every field of scientific interest. Indeed, one can seem to find no part of physics, biology, or psychology where action does not occur. For instance, scientists now suggest that all existence is constantly in a condition of activity. Physical substance as such is no exception to the general rule of perpetual motion or reaction. The atom, as a materialistic unit, appears to undergo an endless succession of movements; the electron seems to move endlessly and in some respects with incredible swiftness; the quantum may be regarded as a unit phenomenon, a center of energy. If one accepts any of the higher types of current metaphysics, one is almost forced to admit of a universe which has at least the property of motion, perhaps involving modes of action and interaction.

The plant kingdom certainly exhibits many modes of response to various forms of stimuli. Aside from growth, plant structures show reactions to certain other plant struc-

tures and make adjustments through the influence of negative and positive tropisms. Many plants respond in peculiar ways to certain stimuli, as if nature had furnished them with a sensitive mechanism designed especially for such stimuli and such responses. The Venus's-flytrap, an insectivorous plant, is a good illustration. When an insect touches the hair-like triggers on the inside of its two spine-fringed, hinged leaves, it will quickly close the pair of leaves, trap the creature between them, and hold him there until the plant digests his body. Euglena, usually classified as a plant, functions in some respects like an animal and perhaps could be classified as plant or animal. The fact is that critical examination appears to cause the conventional line between plants and animals to vanish, a fact which, after all, may be of vast importance.

Lower animals manifest not only sensitivity; they also exhibit the capacity to readjust themselves to some circumstances. Protozoa which have no central nervous system, if indeed any nervous structure at all, respond differently to different stimuli. Amoebae and paramecia, two of the lowest forms of animal life, modify their direction of movement and appear to discriminate between different types of stimuli; they make such movements as are necessary to approach food and escape danger. Sensitivity and response to light, temperatures, and acids are easily observed in the unicellular animals. Higher forms of animal life are keenly sensitive and make adjustments which appear to manifest a high degree of intelligence. Of course the observer of the behavior of the lower animals must not expect lower animals to think and to behave like human beings. He must of necessity interpret the animal mind in terms of the creature's be-

havior under certain conditions. An animal's behavior indicates complex and variable responses, despite our disposition to attribute such activity to instinct only. Ants, bees, wasps, and spiders, for example, do behave for the most part according to pre-established patterns. Bees provide for their colonies; ants are notoriously adept in their plans and in the discipline associated with their hills; species of wasps appear to possess the foresight of an architect in planning their houses, and to have the knowledge of a neurologist in knowing where to sting a captured spider in order to effect paralysis of that source of food for the wasp larva. Apes not only respond to stimuli and follow instinctive patterns; they also, within limits, apprehend novel situations and show evidence of ability to reason.

All in all, from the lowest forms of life to the highest, if indeed not in all modes of existence, there are manifestations of activity and adjustment. In the animal realm there are activities of the organism, especially among the higher species of animals, which appear to be designed to enable the organism to attain to some preconceived objective. It appears to be of minor importance that adjustments made by these animals are efforts to avoid pain or to obtain food, or that their activities generally occur within the sphere of instinctive urges; the important thing is the adjustment, which, interestingly enough, is not infrequently of a rational or semirational nature. All living animal organisms are irritable; and in some respects it appears that many, if not all, of the so-called instinctive urges were accompanied by consciousness during their origin and in the early stages of their development. Our present knowledge of man seems to show that he is no exception. Stages of embryonic develop-

ment and activity, and postnatal urges and adjustments as well, seem to indicate a combination of inherent and acquired patterns of behavior which may be primarily automatic or definitely conscious. We turn now, therefore, to the modes of action which may be observed in the normal human being.

The formation of patterns of action. The gross and mature forms of conduct of the individual human being are easily and generally observed. One sees him as he walks, talks, eats, laughs, throws a baseball, swings a golf club, drives an automobile, controls a locomotive, plays a violin, directs an orchestra, or handles a surgical instrument with uncanny skill. One rarely inquires, however, about the development of such complex and systematic movements, their nervous and conscious basis, their origin, and their transformation into smooth-flowing habitual modes of expression which are easily touched off by some sensory or ideational stimulus.

Prenatal activity. It is commonly thought that learned behavior is restricted to postnatal life. That notion is erroneous. The transition from prenatal to postnatal conditions effects a change in environment rather than any sudden change in the structure of the organism. It is for convenience, and not in strict accord with the facts, that one refers to the learning process as starting at birth. Movements of the embryo seem to occur when and in such ways as the organic development permits. It is believed that bodily movements occur during the second month of embryonic life. By the fourth month development has reached a condition which permits reflex movements of the toes. During the seventh month considerable reflex activity occurs. By

this time the sense organs of the muscles, the joints, the tendons, and the skin, and the neuromuscular mechanism necessary to reflex action, become developed to an extent which permits the stimulus-response activity of the organism. Such tactual, or cutaneous and kinaesthetic sensitivity and neuromuscular activity would seem to provide the individual at birth with reasonably well-established modes of activity, if not some limited conscious experience as well. If this is so, as seems highly probable, that individual at birth is already a complex and highly developed organism, embracing an intricately coördinated sensori-neuromuscular system, which has received some behavioristic discipline. Some patterns of action are thus established before birth; others are formed later.

Postnatal action. No sharp distinction can be made between embryonic and postnatal action, although general differences are clear and numerous. In general, one can say that one's actions can be classified as reflex, instinctive, and learned. These classes frequently merge so that one cannot be distinguished from the others. Consciousness may be associated with reflex action and instinct; it seems invariably to accompany postnatal learning.

Reflex action. Reflex acts are numerous in type, frequent in occurrence, and indispensable to efficient activity of the human organism. The winking reflex, the pupillary reflex, the knee jerk, and the plantar reflex are illustrations of well-known types. Such localized reactions are by no means the only types of reflex action. Let a pin prick the arm, the hand touch a hot object, or pepper irritate the nostrils; reflex response will occur before or despite conscious motivation. Under such circumstances the neuromuscular coördination

is sufficient to provoke almost instantaneous bodily response. The area of response may be small or extensive, and no awareness of, say, pain is necessary. For instance, eliminate the brain of a frog by clipping the cord at the base of the brain; then fasten the frog to an upright board by driving a pin through his head into the board. If a piece of blotting paper soaked with a weak solution of acetic acid is placed upon the dorsal side of one leg, that leg will be moved in an



Fig. 90.—Diagram Showing the Course of a Nervous Impulse over a Simple Spinal Reflex Arc.

effort to remove the irritant. Of course the frog is not conscious. The movement is a simple reflex act. The neural path includes only two neurons: the sensory or afferent which leads into the cord through the posterior horn of the cord, and the motor or efferent which leads out through the anterior horn of the cord to the muscle. The nervous impulse, passing over this reflex arc, goes to the cord over the afferent nerve, and there crosses the synapse to the efferent nerve on which it goes out to the muscle. If, however, the leg to which the stimulus is applied is held and a strong solution of acetic acid is applied to it, the frog, with surprising accuracy will place the opposite foot on the stimulus and remove it. In this case the sensory impulse spreads across

to the efferent nerve of the other leg. If the stimulus is made very intense, the nervous impulse will also extend up the cord and affect the muscles of the front legs and other parts of the body, so that the reflex movements become very complex.

As we have said, in reflex activity consciousness is unnecessary. In the case of a normal human being, such acts may occur without one being aware of the particular act, whether it is simple or complex. Certainly these reflex acts frequently occur before one becomes aware of them. Many such nervous tracts seem to become established as the individual passes from the embryonic state to maturity in order that the nervous tracts which transmit the impulses may be ready as the organism needs them, and in order that action may occur freely and with a minimum of conscious effort. Thus, at the proper time, the chick pecks its way out of the shell, a snake will strike a few minutes after it has been hatched, and a child will grasp tightly a rod which touches the palm of its hands. Likewise, the child seems to be in some measure prepared to swallow and to walk before it has performed such acts. This nervous development is a definite aid to processes of conscious learning and to planned behavior.

Instinct. Instinct is a word used to cover many types of ignorance on the part of those who use the expression. Like will and heredity, it is frequently used as a camouflage for one's lack of information and one's feeble initiative. There are, nevertheless, instinctive urges that play a significant part in human conduct. No satisfactory statement of their origin can now be offered, and no adequate descriptive definition of instinct has been formulated. Let us say, how-

ever, that an instinct is an inherited predisposition of an organism to behave in a given way under certain general conditions. Since the urge or the tendency seems to have its seat in the nervous system, an instinct is also defined as a coördinated series of reflex neural pathways. Everyone is familiar with illustrations of instinctive behavior. Birds migrate, fish swim far upstream to spawn, some animals hibernate, homing pigeons fly almost directly back to their rookery, bees build the cells in which honey is stored, the caterpillar spins the cocoon, the spider constructs a web of intricate pattern, and birds build nests according to the design commonly used by the species.

While the learning process may be aided greatly by instinct, it appears that learning is not essential to many types of instincts, for in numerous cases the animal has never had an opportunity to observe the mode of development of behavior patterns.

Consciously learned behavior. Consciously learned and directed human behavior is action attended by consciousness to such an extent that the bodily correlates occur, and in which, in many respects, the overt bodily activity seems to be a consequence of the mental states. As we have pointed out, we shall make no effort to establish a claim for a mind-body dichotomy, or to set up a system of causal relations. It simply seems to be a fact that modes of bodily responses are established more easily when a condition of clear attention is present, and much less easily, if at all, when one is unaware of the activity.

It is argued that sensory pain or unpleasant emotional behavior facilitates learning certain modes of action when the subject associates the pain with the act to be avoided. There

is some truth in the claim. For example, a turtle will soon learn to take the path on the left rather than that to the right if he receives a severe electrical shock every time he chooses the path at the right. Chickens quickly learn to avoid hot grains of corn placed before them. Electrical shocks soon cause the inhibition of expressions of instinctive impulses in mice. A dog rarely visits again a garbage can

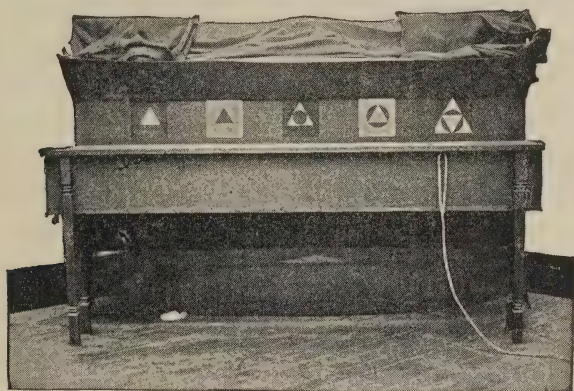


Fig. 91.—Field's Multiple-Type Discrimination Apparatus. (Many different types of animals learn to discriminate between colors, geometrical figures, and visual stimuli which differ in size.)

where he experienced an electrical shock. Nevertheless, pain is by no means the only stimulus to learning; indeed, in many instances, pain may be one of the least desirable and most generally ineffective conditions of consciousness that may be employed to facilitate impression. Perhaps, after all, the vast majority of our learned actions have been acquired in the absence of pain or unpleasantness. Casual as well as critical examination will reveal the influence of many factors; pleasantness, intensity, suddenness, congruity, and other aids to attention are significant in this relation. There

is one thing of which we can be certain—the clearer the state of attention, the more effective will be the learning process.

Now, it is with learned behavior or action accompanied by conscious processes that we are here primarily concerned. What is the relation of the action consciousness to bodily activities?

Action consciousness and bodily action. The persistent mind-body problem can perhaps be approached first by a consideration of the essential nature of conscious processes themselves. In earlier sections the indispensable attributes of consciousness and the nature of compounds were stated. Here it is necessary to call attention again to only one characteristic of every mental state, whether that state of consciousness be simple or complex: a mental process—any mental process—is an active existence, is conscious substance, is a phenomenon. It is not material, not static, and not objective in its nature. Every sensation, image, affective process, perception, and idea may be regarded as an active mental phenomenon. There is no such existence as a static, nontemporal condition of consciousness. All this has been said before, but we should review here these basic tenets of our definition of mind as such.

Moreover, it appears that every state of consciousness has a physiological correlate. Visual sensations have a basis in the retina; auditory sensations have a neural source in the cochlea; tactual sensations arise from the stimulation of various sense organs in that field. Images probably have a neural counterpart in the cerebral cortex; and it appears that affection has its physiological basis in various areas of the body, more especially in the region of the chest and abdomen, and perhaps also in the hypothalamus. Perception,

likewise, has its sensory core and context of secondary sensations and images. This context always includes sensations arising from such sources as eye movements, changes in the muscles of the neck and shoulders, and so on, such as were specified in our study of perception. It is furthermore probable that the larger percentage, if not all, of one's ideas are accompanied by bodily changes. The idea is, in principle, similar to perception, except that image instead of sensation forms the core of an idea. The context consists in part of secondary sensations which, of course, arise from bodily changes. Ideas offer, therefore, no exception to what appears to be a general rule. Emotion is highly perceptive or ideational, and it is also accompanied by numerous gross bodily activities. Withal, unless one persists in injecting metaphysical difficulties, for all present purposes a condition of psychophysical parallelism seems to exist.

There is no final proof that every thought is accompanied by neuromuscular activity; many parts of the body, as the brain, cannot be observed under normal conditions. There is, however, abundant evidence in support of the claim that every percept or idea that implies action is either accompanied or followed by some mode of bodily action. Suppose, for instance, there is attached to one's head an apparatus designed to record every movement of the head during a given period of time; it will be discovered that usually the head will be turned involuntarily in the direction of the location of the object of thought. Again, for example, if a sound occurs at one's right, if one is reminded of an object at one's right, or if one thinks of movement in that direction, one will probably turn the head to the right. The extent of the movement may be so light as not to be perceptible

without the aid of instruments delicate enough to record very slight changes. Nevertheless such bodily responses to thought do occur.

Try a simple experiment. Attach a small weight, say, your watch, to the end of a small cord about five feet long; suspend the object by holding the cord in the hand at arm's length from the body. At first hold the arm perfectly still, and then let your attention be attracted to the weight and think of the weight as swinging around in a circle. Within a minute or two the weight will likely be describing a circle; in some way the muscles of the arm have conformed to the thought. Again, converse with one who lisps or stammers, and notice the strains and pressures associated with your own throat and lips. Watch one's lips and throat as he reads silently, and note, especially with many people, the constant movement of the lips and the throat. Still again, note the strains in your muscles when you feel impelled to step on every transverse line in the pavement, or to touch every board in a paling fence alongside the walk. With many abnormal people such impulses become so strong that the act must be expressed overtly. These are general illustrations; let us return to the use of instruments of precision in an effort to discover less obvious responses.

If one attaches to one's lips an instrument so sensitive as to record any movement that may occur there, it will be discovered that one tends to move the lips in connection with the thought of uttering a word. Likewise, apparatus attached to the throat, near the larynx, records minute and otherwise imperceptible movements of the throat in association with thought. It appears that whenever one thinks of uttering a word some corresponding activity inevitably oc-

curs in the region of the larynx. This may explain the cause of one's hoarseness when one has listened intently to a difficult lecture, and it may show why one's voice is husky when one has worked silently at some strenuous intellectual problem. Carry the application further! It may show why a life devoted to mental problems, usually considered by the uninitiated as affording one a life of ease, so often results in general exhaustion and collapse.

But let us again return to technical facts. Other types of apparatus are attached to the eyelids, to the hands, to the chest, to the abdomen, or to the skin. In every case there seems to be bodily activity correlated with the action consciousness. The hand, for instance, seems to respond to any thought implying its movement. One who is trained to detect such slight movements may be able, while blindfolded, to guide one to a concealed object or to some designated part of town by observing the minute movements of the hand or the arm which he holds. Horses and dogs are thought to employ reasoning ability when they solve simple problems in mathematics or designate some object named by the trainer, when, in fact, the animal is guided by some observed slight movement of the trainer's head or eyes.

Galvanic changes also occur. If the electrodes of a psychogalvanometer are attached to one's fingers or to the skin, galvanic changes associated with thought may be detected. These disturbances are especially abundant during emotional states, but they seem also to occur during other conditions of mental activity.

Empathy offers many illustrations of the action consciousness. In empathy one tends, without realizing it, to project oneself into some perceived object and so to experience

whatever that object appears to experience under the circumstances. Columns too thick for their height, archway entrances that are too low and massive, statues imperfectly balanced, wrestlers who appear to undergo severe strain, amateur toe dancers and contortionists arouse empathic bodily reactions in the observer. Experiences of, say, pressure and strain occur when one observes such objects or witnesses such activities. As one intently watches a football game, one may suddenly discover that he is leaning heavily against his neighbor as the players rush forward in an effort to advance the ball. Not infrequently one may observe that a passenger applies the brakes by pressing on the floor board when the automobile has to stop. In all such cases, the perception is attended by motor activity; in some way the thought gains access to avenues of bodily responses and there expresses itself.

As was seen in the discussion of perception, these bodily responses themselves stimulate numerous sense organs of touch and thus add greatly to the context of the meaning complex. It would seem, then, that a train of thought processes may not only be enhanced in meaning, it may also become prolonged by such apparently reciprocal interstimulation of mind and body.

Nature of the action consciousness. Thus far our discussion has been concerned with the existence and the general development and expression of action. Action, as bodily response, has been regarded here as the physiological correlate of a state of consciousness. Bodily activity can be observed and recorded in various ways; its general nature is known. But what is the nature of the pattern or the series of patterns of the action consciousness itself? In our effort

to give a critical answer, it appears to be advisable to turn to a case in point, namely, the simplest type of the reaction experiment.

The reaction experiment. In the simplest form of reaction experiment the observer sits by a table and places his finger on a key which, with minimum effort, he can press and break an electric circuit started by the experimenter. The experimenter presents a stimulus—visual, tactual, or auditory—at the instant he starts the electric circuit, and the observer presses the key and breaks the circuit the moment the stimulus is experienced. In this simple form of the reaction experiment two types of instructions are given to the observer; the first is designed to cause his attention to be attracted as completely as possible to the stimulus itself, while the second aims at having the muscular reaction occupy the primary place in consciousness. For example, in the first, the instruction may be stated thus: “You will see a red card; react when you see it.” Here the emphasis is placed upon the appearance of the stimulus; the reaction is of secondary consequence. This is the stimulus attitude. In the second instance, however, the instructions are as follows: “You will see a red card; react *instantly* when you see it.” In this case the emphasis is obviously upon the reaction itself; it is the reaction attitude, and the observer is all “set” to press the key the moment the stimulus appears. The same types of instructions are given when auditory or tactual stimuli are employed.

The reaction attitude. Now, the type of instructions given to an observer in no small measure determines the nature of his action consciousness; the stimulus attitude gives rise to conditions of consciousness quite different from those set up

by the response attitude. In each case the action consciousness may be divided into three periods, namely, the fore-period, the mid-period, and the after-period. The fore-period extends from the warning signal to the instant the stimulus appears; it is generally a period of anticipation. The mid-period is the interval during which the bodily response required by the instructions is actually made. The after-period is one of reflection and introspection.

When the stimulus attitude exists, the observer's consciousness likely consists of expectation, that is, of imagery of the stimulus—internal speech designating the stimulus by name, kinaesthesia, and accommodation. There is frequently a definite "build up" concerning the stimulus before it is presented. In some instances the consciousness forming the anticipation is so vivid that the substitution of another stimulus would not be noticed for a moment. It is as if there is such accommodation of attention to the imagery or idea of the stimulus that, when the stimulus does appear, it is immediately very clear in consciousness. In addition to the expectation of ideation with reference to the stimulus itself, there is an inclination to tie the experience up with the bodily response requested by the instructions. Attention to the idea usually, at best, wavers enough to permit waves of kinaesthesia, as it were, to move about the hand at the key. It is like one's experiences when one is waiting for the signal to start the 100-yard dash; as he listens alertly for the pistol shot, waves of kinaesthesia appear in his legs.

When the response attitude is set up by the instructions, the stimulus falls somewhat into the margin of consciousness and the thought or anticipation of the movement itself is in the focus of attention. This state of anticipation may con-

sist of several parts. It is likely to be composed primarily of kinaesthesia converging especially in the finger resting upon the key of the reaction apparatus. These sensations may become so clear that the finger, and even the hand and arm, may appear to be a focus of strains and pressures. This kinaesthesia is at the same time tied up with the idea that a stimulus will appear. The stimulus attitude is, however, here so vague that any stimulus in the field in question may touch off the reaction. Let us take again the illustration of a runner about to make the 100-yard dash. If the coach has definitely instructed him to run the instant the signal is heard, the runner may be so tense kinaesthetically and thus so attracted to the idea of muscular reaction that any noise may produce the reaction. It is often in this way that false starts occur in track meets and in regattas. The runner's or the oarsman's consciousness and his neuromuscular mechanism are so accommodated to muscular response that a weak stimulus can cause instantly an intense reaction. The condition is somewhat like that of a frog which has had an injection of strychnine; the animal's synapses appear to be closed and the nervous impulses are thus so freely transmissible that a slight tactual stimulus causes a condition of general tetany.

The mid-period consists roughly of two phases. The first is the identification of the stimulus, and the second is the reaction itself. The perception of the stimulus may be swift and clear or vague and indefinite, according to the attitude as set up by the instructions. The reaction phase is largely kinaesthetic, and may include internal speech or laryngeal strains. The clearness of this phase is usually in inverse proportion to the degree of ease with which the act is per-

formed; some reactions are so nearly automatic that one is hardly conscious of them. This corresponds to everyday experiences, as anyone will know who reflects upon the way in which he responds to novel instructions.

The after-period consists largely of kinaesthetic relaxation and of introspection. Kinaesthesia may arise from muscular readjustment, internal speech, and general relaxation from accommodation. The introspection usually consists of the perception of the result of the reaction, verbal comment which may be audible or not, and ideational reflection concerning the accomplishment of the action response.

The course of the three periods of the reaction consciousness is determined by the instructions. The train of conscious processes is started by the instructions and follows generally a narrow and restricted course, just as the runner's course, from the "get set" to the finish line, is determined by the particular circumstances of the race. He is not attracted by the crowd and other unrelated matters. So, in a simple reaction one's mental processes are restricted. When a baseball pitcher throws the ball, he is directed by the idea of the corner of the plate over which the ball shall pass; there is no place in his consciousness for reflection about the manufacturer of the ball, the retail merchant who sold it, its fiber contents, and so on. A successful golf player must eliminate self-consciousness and ignore the gallery. Likewise in one's everyday experiences the idea, the motive, or the objective does much to determine the course of thought and of bodily activities, whether it involves only a momentary act or the work of months or years.

It should be noted here that in experimental work the reaction experiment may be made very complex by changes in

the reaction apparatus and in the instructions given to the observer. For example, the observer may be told that he will be shown a red or a green stimulus, and that he is to react only when red appears; or that a tone or a noise will be heard, or that a warm or a cold stimulus will be applied to the skin. Under such conditions, when the observer is to respond to only one of two or more stimuli, apprehension must be clearer than when only one stimulus is used. The experiment may be such as to require response with the left hand when red is exposed and with the right hand when green is presented. Or the experiment may be made even much more complex by having ten different types of stimuli, a reaction key for each type of stimulus, and instructions may be given which require response with a given finger or thumb when a certain type of stimulus is experienced. Multiple choice and multiple reaction experiments, especially at first, make the action consciousness much more complex than when the simple form of experiment is employed. In general, however, the course of consciousness is approximately the same in both types of experiment; the difference is primarily one of complexity and clearness.

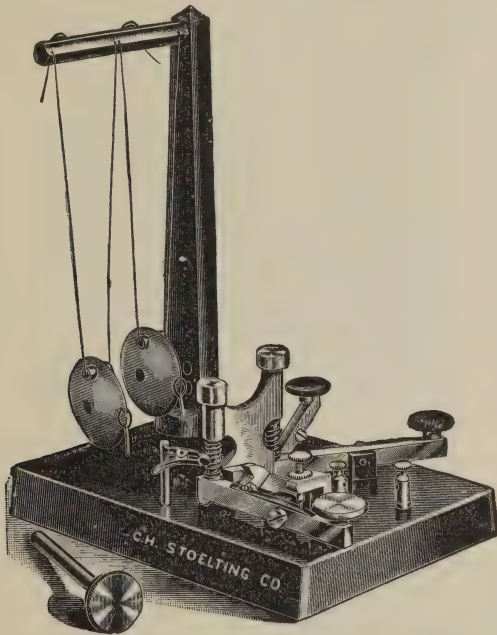
The reaction time. Obviously the total reaction experience runs a temporal course. Reaction time is the interval between the moment the stimulus is presented and the instant the observer presses the key or makes the muscular response. It is a well-known fact that such an interval occurs. It is also now generally known that different individuals have different reaction times, and that the response of the same individual varies with different instructions and attitudes.

The investigation of reaction time began under interesting

circumstances. In 1796, an observer employed at the Greenwich Observatory, in England, was discharged because of his apparent carelessness in noting the exact instant a star passed the hair-line of the telescope lens. He reported the moment of transit as more than one half second later than did other expert observers, and consequently he was considered inefficient. It was discovered later that the reaction time of the observers in the observatory was a relative rather than an absolute interval. Individual differences were found to play a prominent part in reaction-time intervals, a fact now well known by those who give tests to determine one's fitness to drive an automobile or to handle machinery which requires a short reaction time.

Psychologists now use various types of chronometers in order to measure reaction time correctly in terms of units of one-thousandth of one second, that is, in terms of milliseconds. These chronometers, when used to obtain a large number of records of reaction time intervals, show clearly the differences in reaction time as caused by differences in personal equations, by different types of instructions, and when physical stimuli are applied in different sense fields. The instruments are designed to operate as automatically as possible. The electrically driven timing device is started at the moment the experimenter presses his key, which instantly presents the stimulus; it stops when the observer, in reacting to the stimulus, presses his key and breaks the circuit. The time interval is thus recorded and may subsequently be read. Make and break keys similar to telegraph keys are frequently used. Other types of keys control the chronometer by means of movements of the lips or the eyelids. Various stimuli, as colored lights, colored cards, tones,

noises, and various tactual stimuli, are presented automatically so that the time at which the stimulus is presented and the beginning of the recorded time interval will be coincidental.

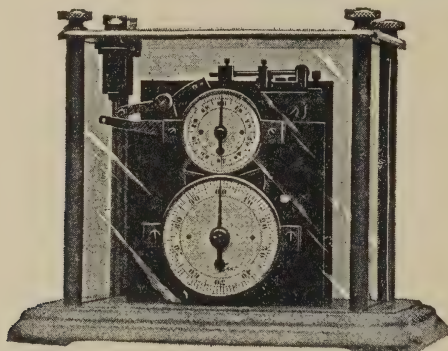


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Fig. 92.—Sanford's Vernier Chronoscope.

The reaction time varies considerably under different circumstances. Different observers, varied instructions, stimuli applied in different sense fields, the same type of stimulus applied to diverse areas of the same sense organ or sense field, the form and size of the stimulus, and an increase in the intensity of a given type of stimulus give different reaction time intervals. Although no absolute time intervals can be

given, the following illustrations show, in milliseconds, the effects of different conditions. When the stimulus attitude exists, the time is approximately as follows for different sense fields: vision, 290 ms.; audition, 225 ms.; touch, 190 ms.; smell, 800 ms.; taste, 1080 ms. The reaction time under the response attitude is usually less than one-half that of the



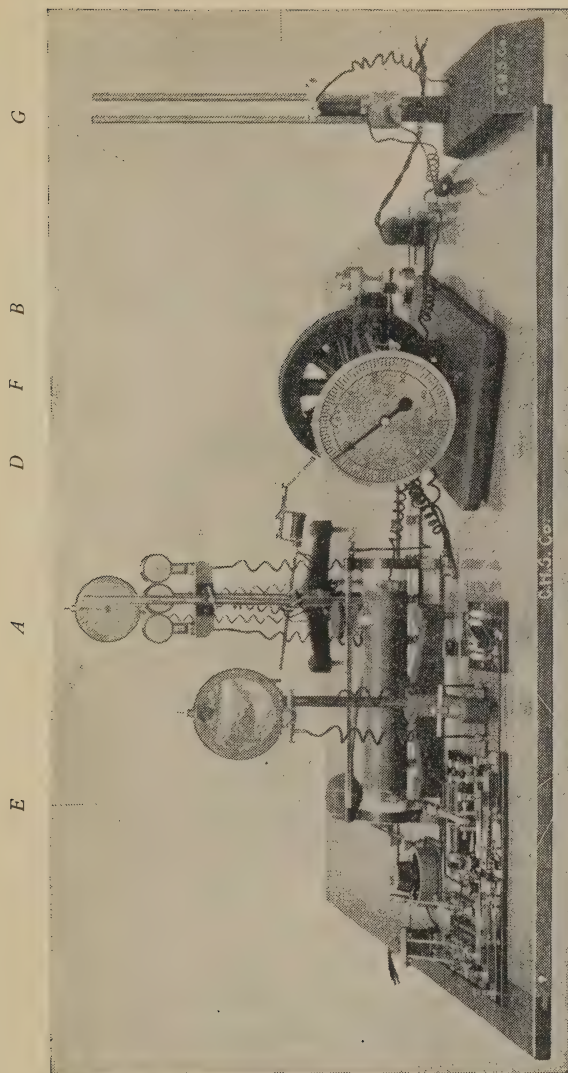
C. H. Stoelting Co.

Fig. 93.—Hipp's Chronoscope.

stimulus attitude, as the following statistics show: vision, 180 ms.; audition, 120 ms.; touch, 115 ms.; smell, 200 ms.; taste, 305 ms.

In vision, the size, the shape, and intensity of the stimulus, and the point at which the image falls on the retina give, in general, differences in the time required for response. Larger and more intense stimuli give a shorter reaction time, and the reaction interval is shorter when the image falls on the *fovea centralis* than when it falls toward the periphery of the retina. In touch, the reaction time required for stimuli applied to the forehead is longer than for stimuli applied to the hand; reaction to intense stimuli is quicker than to weak stimuli; the reaction time is shorter when the stimulus

C



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H

Fig. 94.—Dunlap Reaction Time Apparatus. (A, voice keys; B, chronoscope; C, electric tuning fork; D, three-lamp visual stimulus; E, reaction key; F, tactual stimulus key; G, telegraph sounder for auditory stimulus; H, control switches.)

is applied to the right hand than when it is applied to the left.

There are also wide ranges in reaction time, caused by individual differences in ability. People of low mentality usually react slowly. It must not be understood, however, that there is necessarily a close correlation between quick reaction time and intelligence, and slow reaction time and subnormal mentality; some individuals of normal or superior ability react slowly, and it is only the definitely feeble minded who may generally be expected to respond slowly. It is true, however, that if the reaction time is short in one sense field, it is also likely to be short in other sense fields; if, likewise, it is slow in one field, it will likely be slow in the others. Training improves one's technique and thus reduces his reaction time within limits only; it does not increase one's native ability.

Reactions and loss of meaning. One who has acted as an observer in the reaction experiments knows that, at first, the action consciousness was charged with meanings. The mind was so filled with sensory and imaginal experience that the work of observation was difficult. Yet, after long practice, many apparently irrelevant meanings dropped off, much of the context was lost, and the experiment seemed to be much simpler. What had happened? During the stimulus attitude the observer was able to exclude much of the context associated with the expectation of the stimulus, and he was thus able merely to wait for the stimulus; the intent to react remained definitely present, but it also lost much of its kinaesthetic context. During the response attitude a large part of the context was also lost as the observer became skilled in responding. In both instances the nervous "set"

had become so well established as to be almost habitual in nature.

Now, that is precisely what occurs in one's everyday experiences. A large part of the context first associated with one's learned responses falls away, so that finally a simple stimulus object or an idea may easily touch off a complex movement which runs a definite course. For instance, as one learned to write, one formed each part of each letter of a word with effort and with a wide variety of meanings; now, however, the movements of the hand and arm automatically form the word as soon as the idea occurs, and no attention is given to the different parts of the letters or words. One learned with difficulty to use words orally; now he almost never thinks of a word before it is uttered, or the sequence of words that form a sentence. The idea appears; the words simply follow. The expert typist first learned to correlate stimuli and movements of her hands and fingers; now such movements automatically follow the perception of the material to be copied. The baseball pitcher learned to throw a ball; now he is no more aware of each movement of his arm and body than the proverbial centipede is aware of the movement of each one of his legs. The pianist at first learned with all of the complexity of consciousness and effort experienced by a beginner; now the mere sight of the score easily and freely effects all movements required by it.

Thus, reactions, at first very difficult and attended by rich sensory and ideational context, upon repetition and with the development of familiarity, lose much of the context and become almost habitual or automatic. In this way one's life becomes more and more an accumulation of sensorimotor and ideomotor responses, so that one goes along walking,

eating, hitting golf balls, tumbling light switches, operating machinery, talking, writing, driving automobiles, and doing a thousand other routine things habitually. And it is well that it is so, for the formation of such modes of habitual actions leaves opportunity for the acquisition of new perceptions, ideas, and forms of behavior. After all, mental simplification permits mental growth. It, moreover, permits the formation of the habits of mind and body and the patterns of conduct that form a definite and tangible asset to one's character.

Will and personality. Familiar definitions and discussions of the will and of personality are usually expressed in non-descriptive terminology. They usually give no adequate or satisfactory analysis of the urge or drive which is usually called the will, or the peculiar complex or mosaic of traits frequently referred to as personality. No final or satisfactory analysis of personality need be expected here. Indeed, no final and absolute characterization can be made until a complete metaphysics and a comprehensive descriptive treatment of man shall have been obtained. We shall, therefore, of necessity have to restrict our discussion to the limits of some observable facts. Action throws some light upon the nature of a human being with respect both to his inherited characteristics and to his acquired traits.

At the outset of this study we assumed, at least provisionally, a monistic conception of man. It may be inaccurate and inadequate; it is indeed subject to severe criticism and provokes numerous problems. Nevertheless, it both suits our purposes and is as clear metaphysically as is any pluralistic conception. Our dichotomy of mind and body was, as stated, merely an arbitrarily established convenience for study. We

need it as a method here in the closing section of the treatment of action; for, in an examination of drives or expression of will and traits of personality, one must examine characteristics not merely in their own right but also with respect to their relation to the whole, of which they may be, after all, only modes of manifestation.

Heredity provides the individual with his potential body and mind. It is likely that, at the moment of conception, all the characters or factors which normally determine one's bodily traits and mental capacity are present. These determinants apparently set the course and fix the limits of the maximum possible development of body and mind. The proper place to study biology is in the field of biology under the supervision of a competent biologist; it is necessary, however, to point out here that principles of heredity do obtain with respect to fundamental bodily characteristics and mental capacity. The psychologist can say with reasonable assurance that no individual ever increases the mental capacity which he possessed at birth. One's native potential ability may not become developed, and many influences may cause it to become decreased; nothing ever seems to increase it. The individual, then, at birth may be regarded as a highly complex organism and a potential mind, capable of growth according to his established hereditary traits. Instinctive urges perhaps belong both to heredity and to environment. By definition, they consist of nervous coördinations acquired during the history and experience of the race, and are transmitted by heredity to the individual. The instinctive behavior of an individual is started by some bodily change or by some sensory or ideational experience. With its different forms of equipment, the organism is normally well prepared

for the reception and organization of mental experience and the formation of numerous and diverse patterns of expression.

We have discovered how, from the point of view of descriptive science, the data of mind are acquired, and how they become associated to form new data, meanings, and such sequences as are usually called reasoning. The association of thought processes, whether simple or complex, spontaneous or selective, occurs through the operation of psychological law—a tendency apparently related to body as well as to mind. In every instance, the psychological processes are active; they are mental substance which constantly “flows” in one direction or another, according to its own nature and according to influences acting upon or associated with it. Now, there are two general facts which need to be considered here: they are the formation of choices and the establishment of personal modes of behavior. The two cannot actually be separated except arbitrarily for the purpose of discussion.

Choice. The normal individual is constantly surrounded with and bombarded by physical stimuli. Each physical stimulus, in its action upon a sense organ, clamors for a place in consciousness. Many of them do gain admission as simple or complex sensory experiences. Now, when sensory experience occurs, two things follow. First, other experiences, both sensory and imaginal, instantly become associated with the new experience, and meaning or perception occurs. The affective process may also accrue to the sensory experience or to the perceptive complex, as the case may be, and make the experience a pleasant or an unpleasant one. Second, the sensory experience or the perception, if not both, becomes to some extent fixed or recorded in mind and is by virtue of that fact made available for future use.

Thus, it is in this way that the reception, the association, and the retention of new data occur.

But this is not all. Mind, by virtue of its very nature, not only constantly receives sensory impressions; it also associates old data and forms new images and ideas. By such associative tendencies new modes of thought are formed. In every case there are neural or neuromuscular correlates of the psychological processes. Moreover, any new association formed and any new datum produced are likely to become permanent traits of one's mental equipment. Repetition tends definitely to strengthen associative bonds and fix habits of thought.

Now, it is in this way that one's mental standards become developed and established. Here is to be found, from the point of view of description, the secret of the formation of inclinations, motives, ambitions, and ideals. Diversity of standards of conduct, moral codes, social practices and tastes, such as may easily be discovered among different people, has its cause in differences of psychological experience and discipline. Descriptive science has no place for values; there is, however, no reason why one should not state here that value is meaning, and that meaning is association. It follows that standards of values—moral and ethical—are determined by the type of associations established in an individual's mind.

Will. It is in the active nature of mind and its associations that determination or will seems to appear. So long as the associations flow smoothly and without interruption, no evidence of will appears. When, however, there is conflict, something does arise. What is it? Will is experienced when a conflict between impulses or objects of thought occurs, and when one recurrent idea or some object of thought gains precedence over the others. In this struggle

there appear such experiences as perceptions, imagery, ideas, and, usually, a vast amount of kinaesthesia, since the accommodation of mind and body occurs first in this direction and then in that direction. The persistent, recurrent object of thought finally dominates and wins. The strongest object of thought won in the struggle. Why? Not necessarily at all because of its own intrinsic nature or intensity. It won because its correlated associations of mind and body enabled it to win. The mental data, the associative tendencies, and the habits of bodily response were its shock troops. One has only to observe one's own experiences or those of other people to discover the powerful influence of associative tendencies that have become established during one's lifetime.

Personality. This word, as we have said, defies satisfactory definition. Let us say, for the present purpose, that personality consists of those peculiar characteristics of an individual which distinguish him from other individuals. His personal appearance, his habits, his mannerisms, his standards of honor and honesty, his ideals, and so on—all go toward forming that composite of body and mind which one calls personality.

That biological factors, such as the endocrines, have much to do with the formation of individual differences cannot be denied; abnormal psychology has on record too many cases in point for one to disregard scores of biological influences that shape personality. Hereditary traits, diseases, glandular disturbances, malnutrition, accidents, and a score of other things could be listed here. Let us, however, leave those cases to the abnormal psychologist and look at the so-called normal human being.

Among these so-called normal people one finds almost every conceivable type of attitude and mode of expression. There are the cultured and the ignorant, the refined and the slovenly, the ambitious and the indolent, the temperate and the debauched, the honest and dishonest, the thrifty and the wastrel, the moral and the immoral. What makes these differences? Heredity gives capacity, but it does not make a man honest or a liar, temperate or a drunkard. The secret, generally speaking, is to be found in the type of mental data, the associations, and the habits, together with the correlate discipline of bodily habits of the individual. Given an individual of normal body and mind, we can train him from infancy in mental and bodily habits so that he will conform to any one standard of personality, whether desirable or undesirable. When parents and others cease evading their own responsibilities in this relation and see facts as they are, the effects of mind-body training will be observed clearly. Anything that attracts the attention of a child is that child's psychological environment and contributes to the sum total of the training and, therefore, to the personality of that individual.

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